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(54) **ROTARY-WING, HOVER-CAPABLE AIRCRAFT AND METHODS**

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B64C 27/10 (2023.01)
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(52) **U.S. Cl.**
CPC ***B64U 70/70*** (2023.01); ***B64C 27/10*** (2013.01); ***B64C 27/50*** (2013.01); ***B64C 39/024*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC B64U 10/17; B64U 70/50; B64U 70/70; B64C 11/28; B64C 27/50; F42B 10/58
See application file for complete search history.

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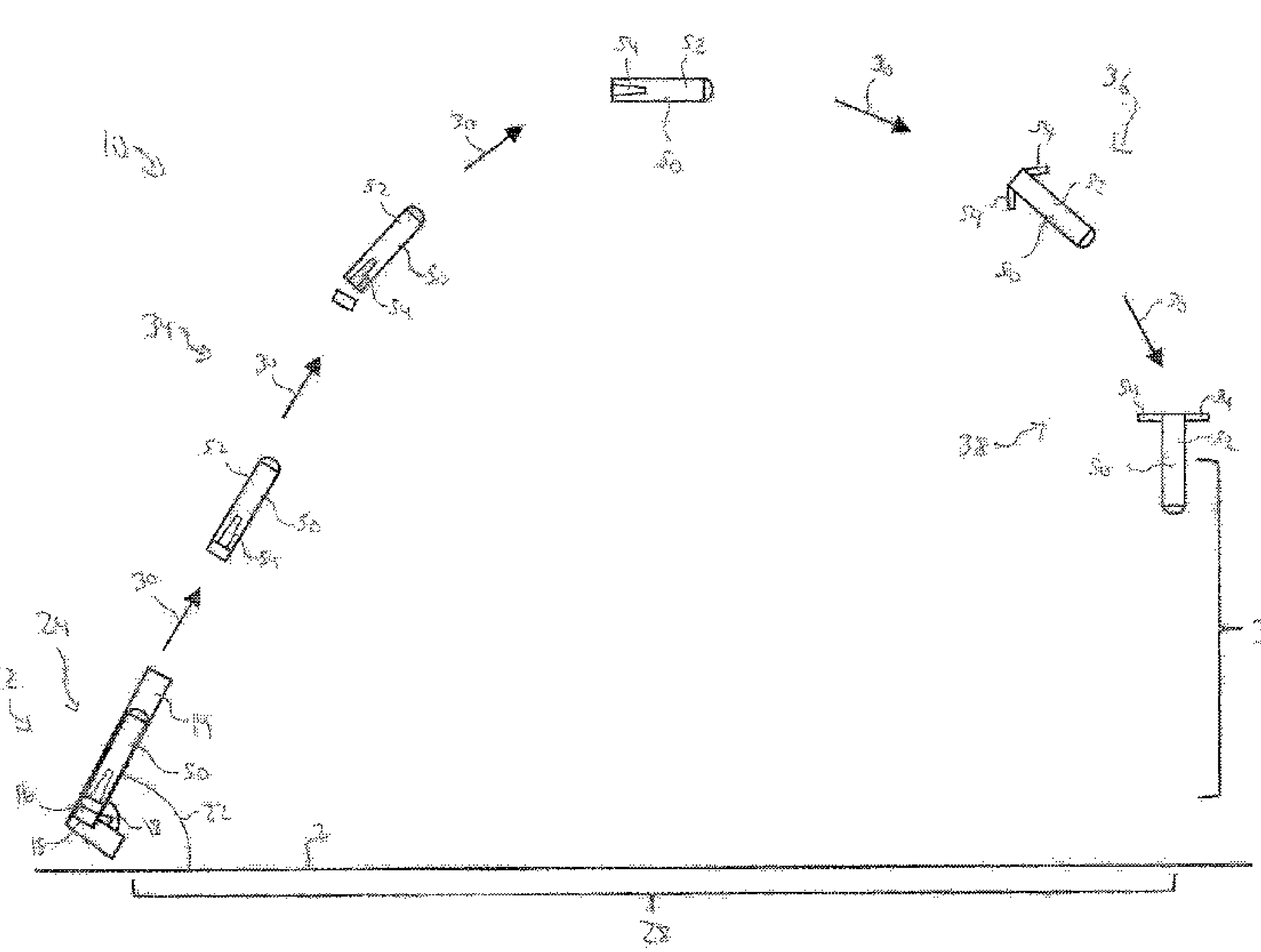
(57) **ABSTRACT**

A projectile-launched aircraft system includes a projectile launcher including a triggering mechanism, a rotary-wing, hover-capable aircraft including a rotor assembly that includes at least one rotor blade, wherein the rotor blade includes a stowed configuration and a deployed configuration that is circumferentially spaced from the stowed configuration about a pivot axis, wherein, upon actuation of the triggering mechanism, the projectile launcher is configured to launch the aircraft along a flightpath.

19 Claims, 8 Drawing Sheets



(51) **Int. Cl.**

B64C 27/50	(2006.01)
B64C 39/02	(2023.01)
B64U 10/10	(2023.01)
F42B 10/14	(2006.01)
B64U 80/00	(2023.01)
B64U 101/30	(2023.01)
F41G 7/36	(2006.01)

(52) **U.S. Cl.**
CPC ***B64C 39/028*** (2013.01); ***F42B 10/14*** (2013.01); *B64U 10/10* (2023.01); *B64U 80/00* (2023.01); *B64U 2101/30* (2023.01); *F41G 7/36* (2013.01)

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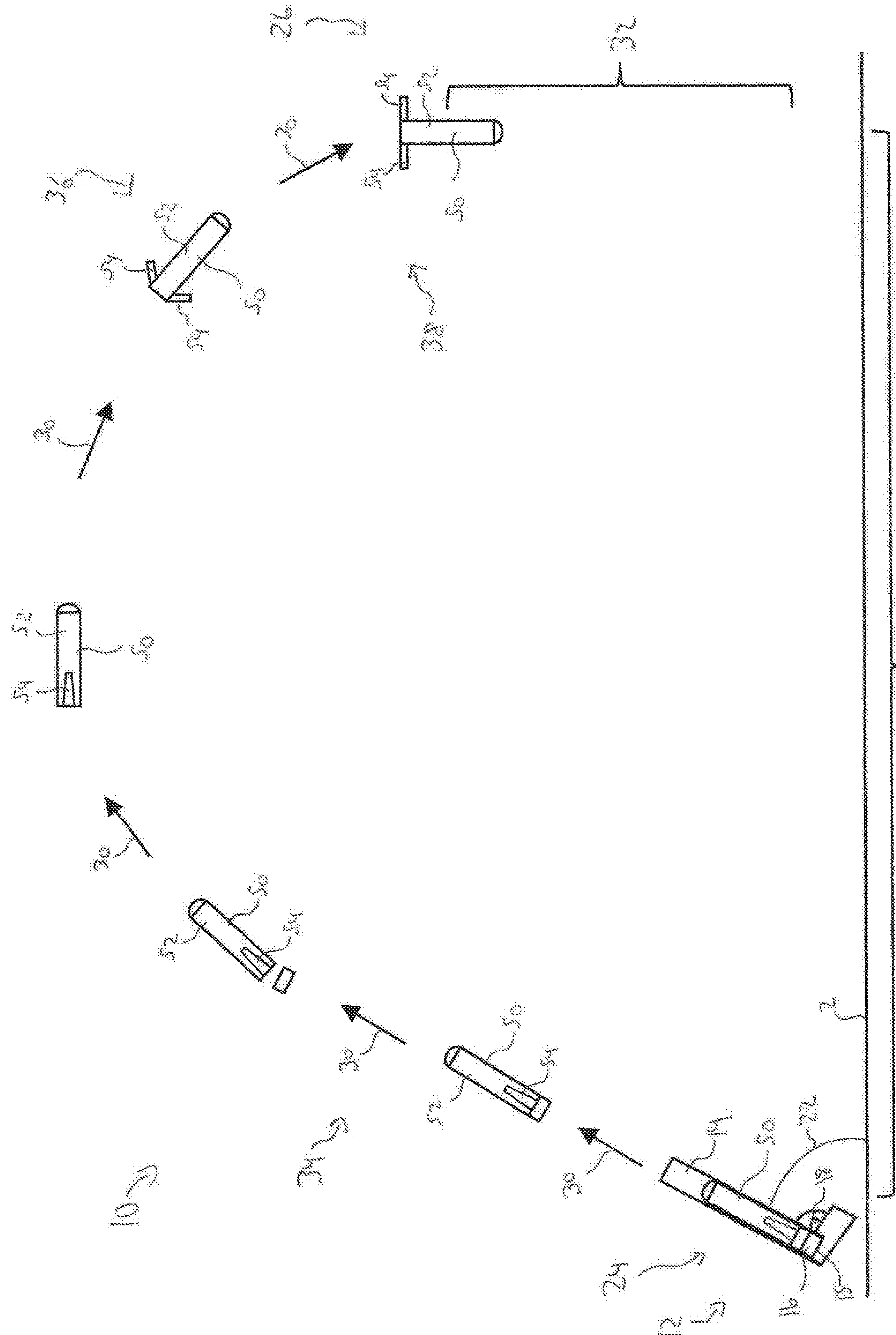

FIG. 1

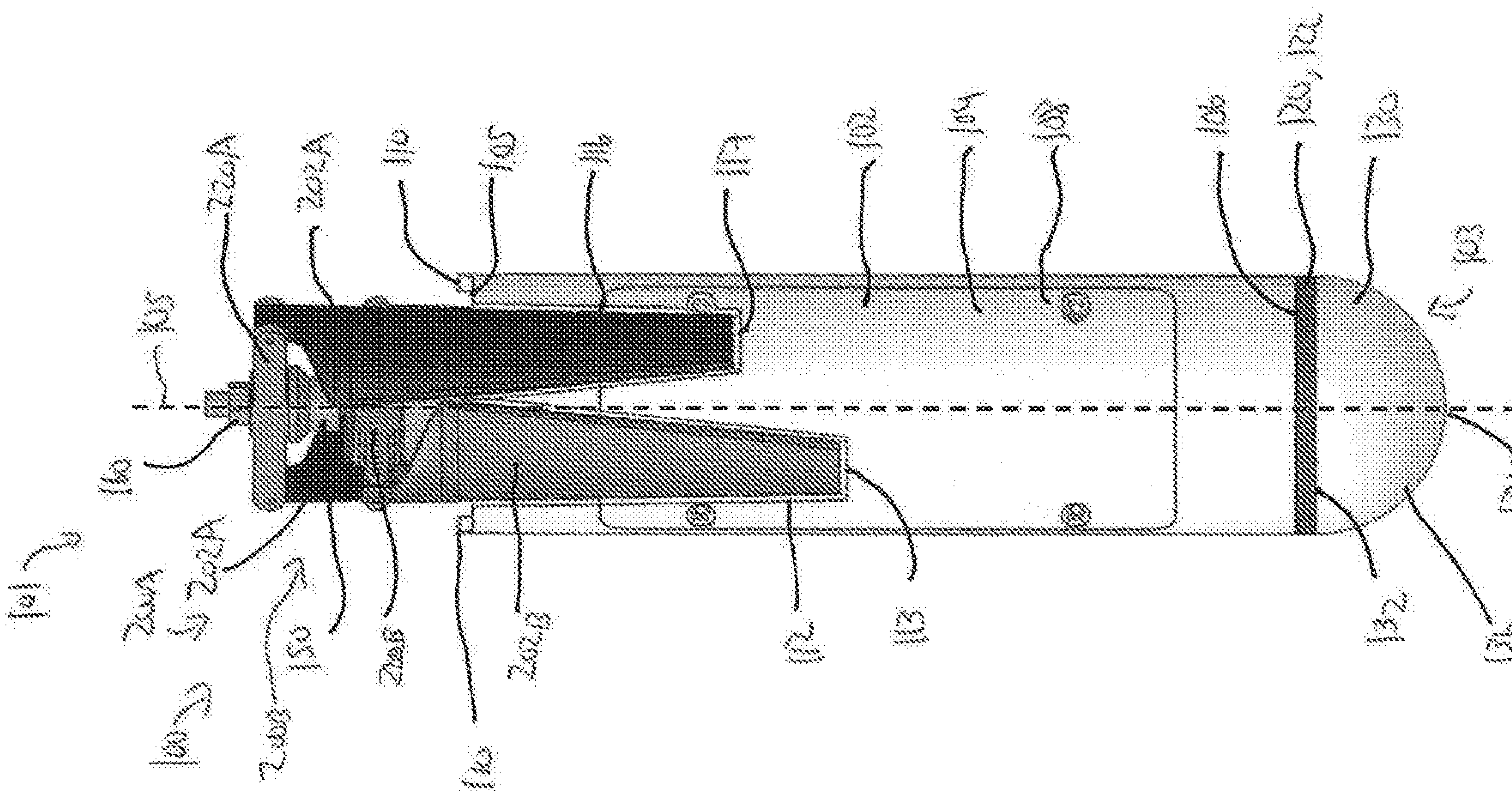

FIG. 3

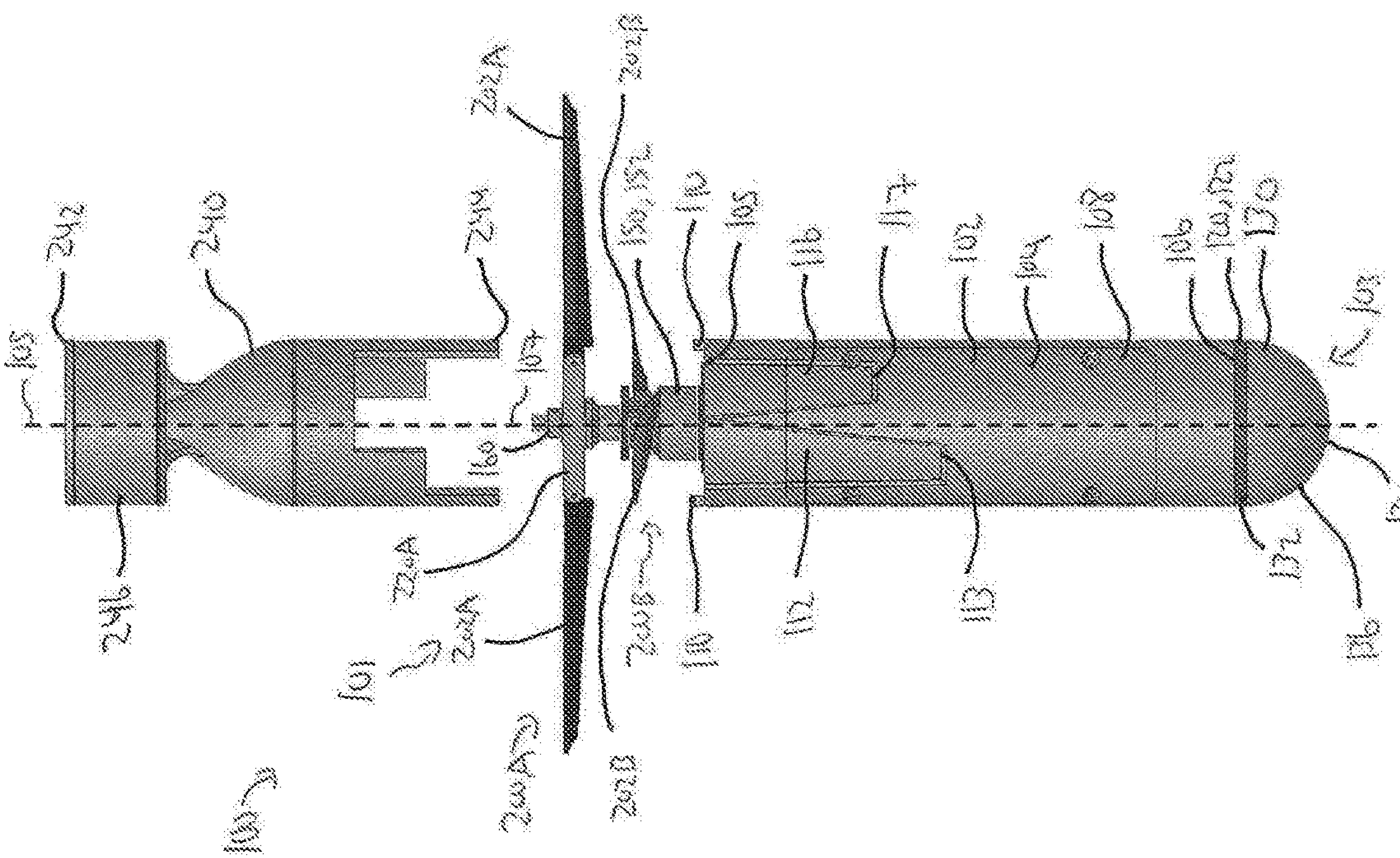

FIG. 2

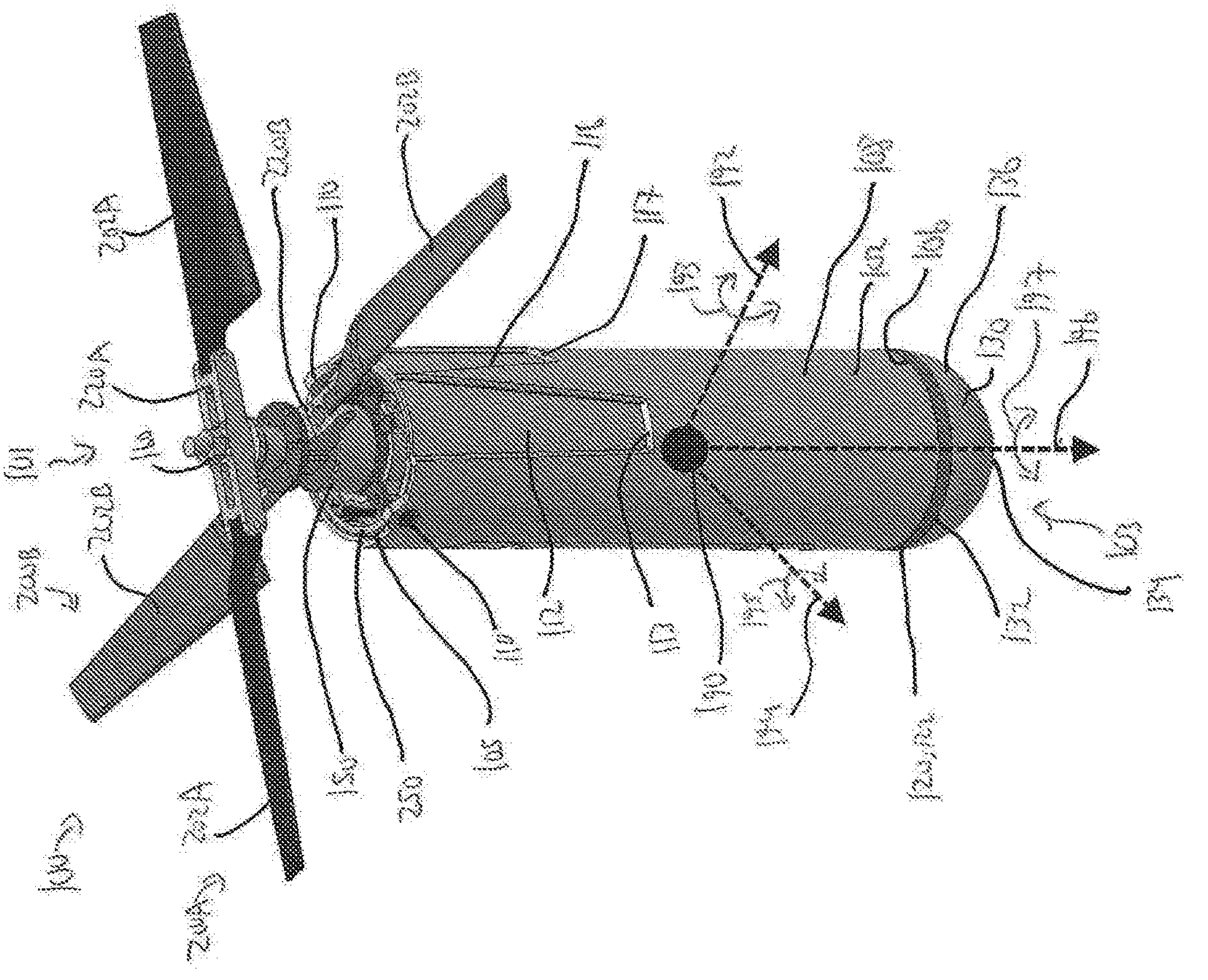

FIG. 4

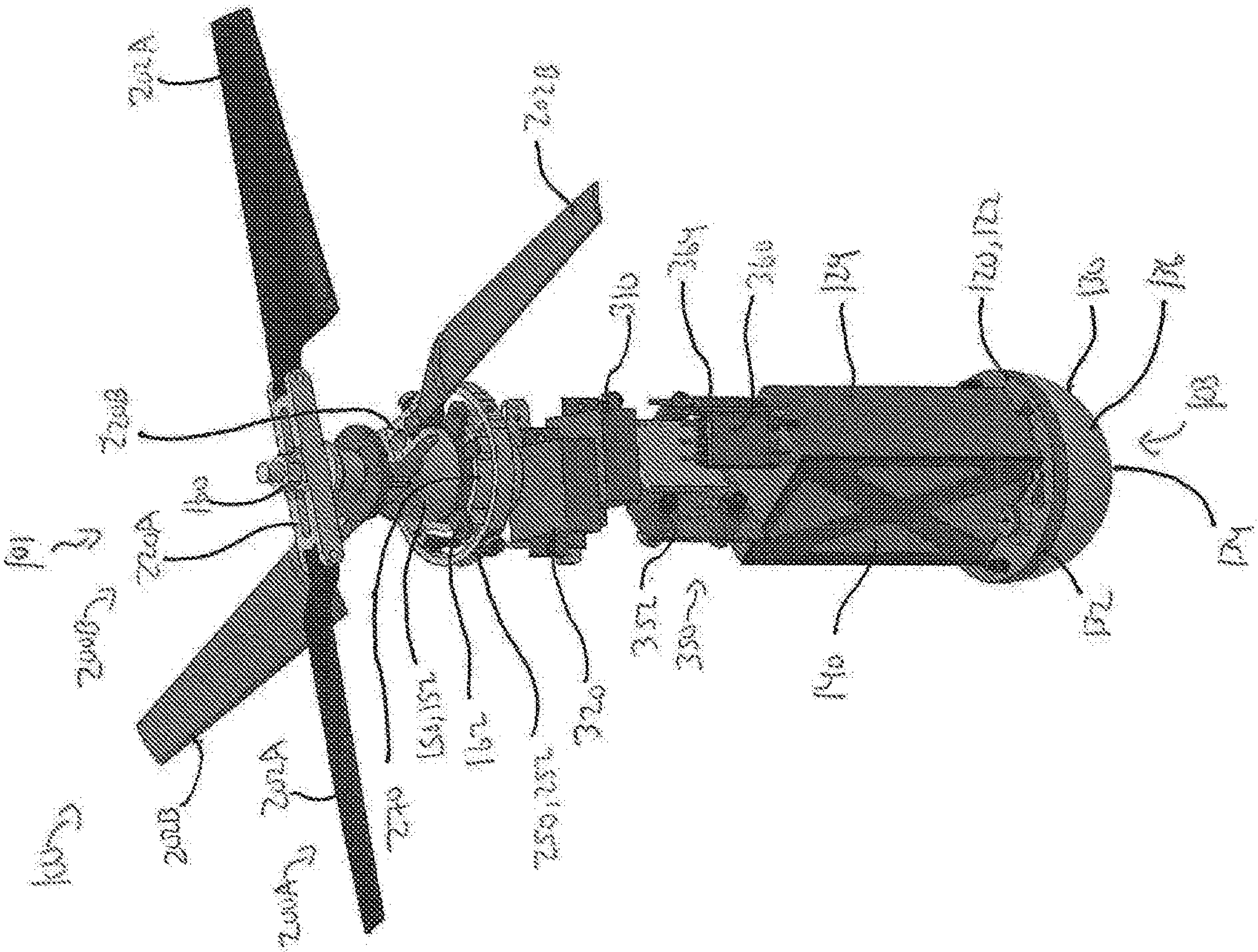

FIG. 5

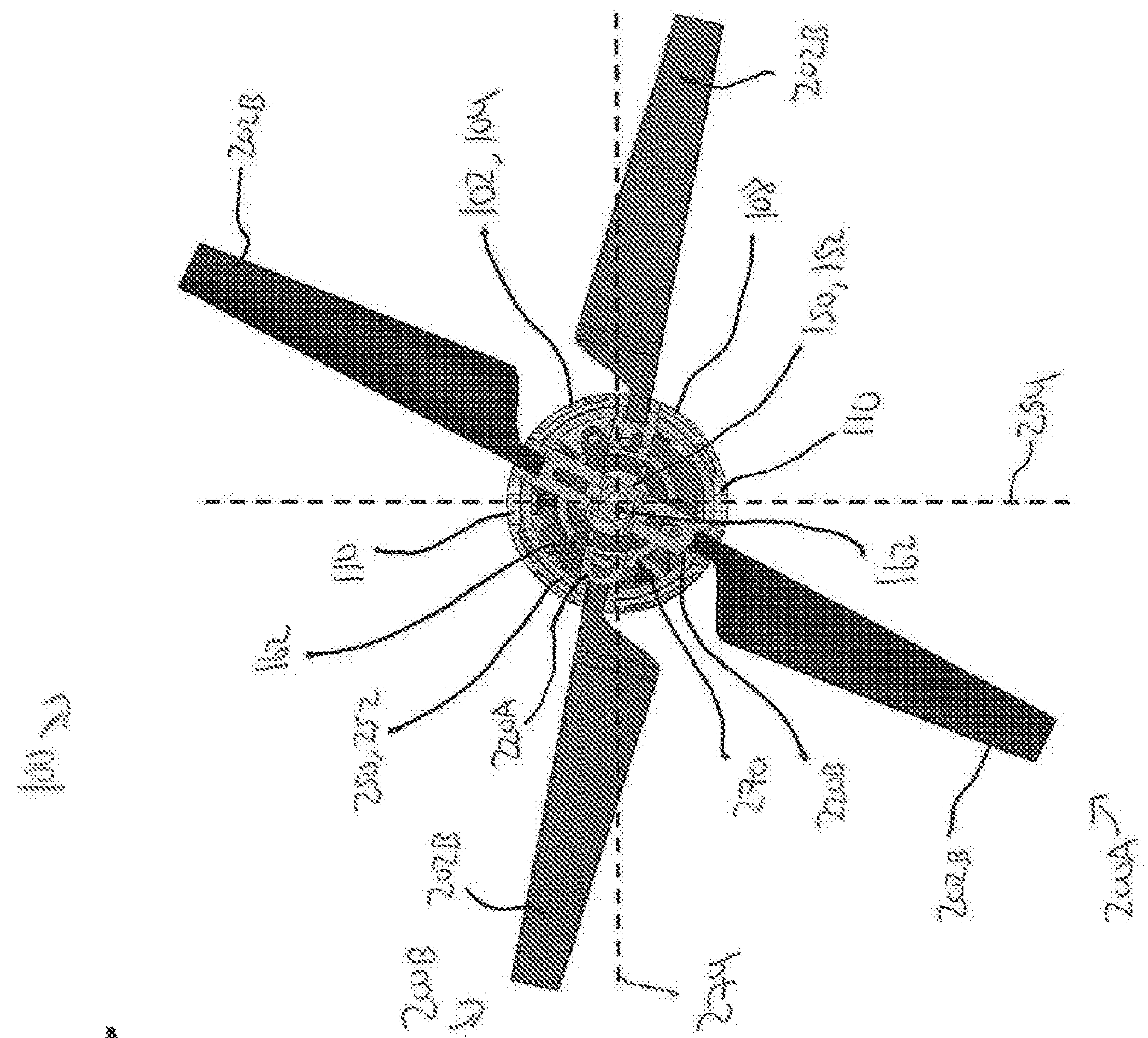

FIG. 7

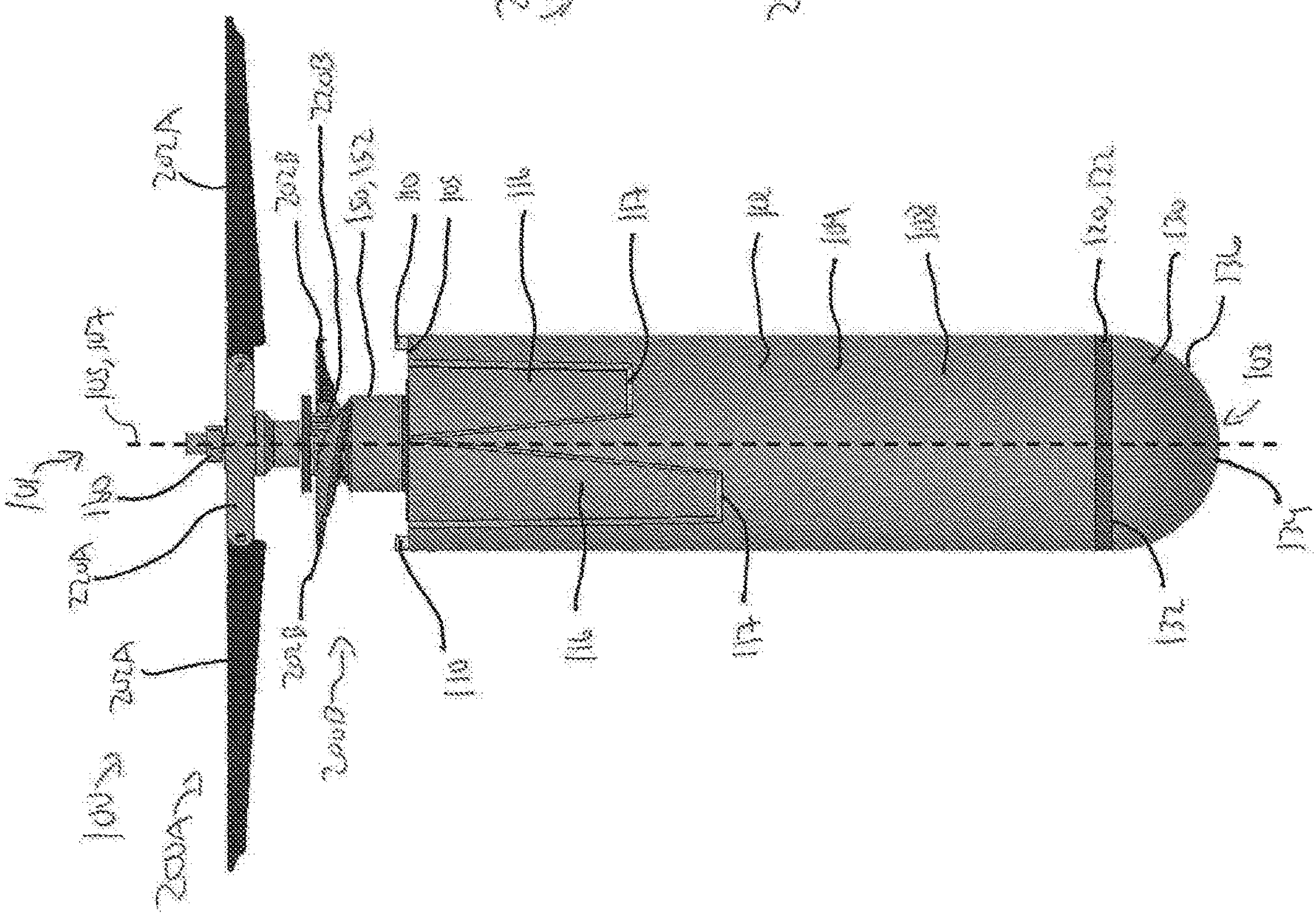

FIG. 6

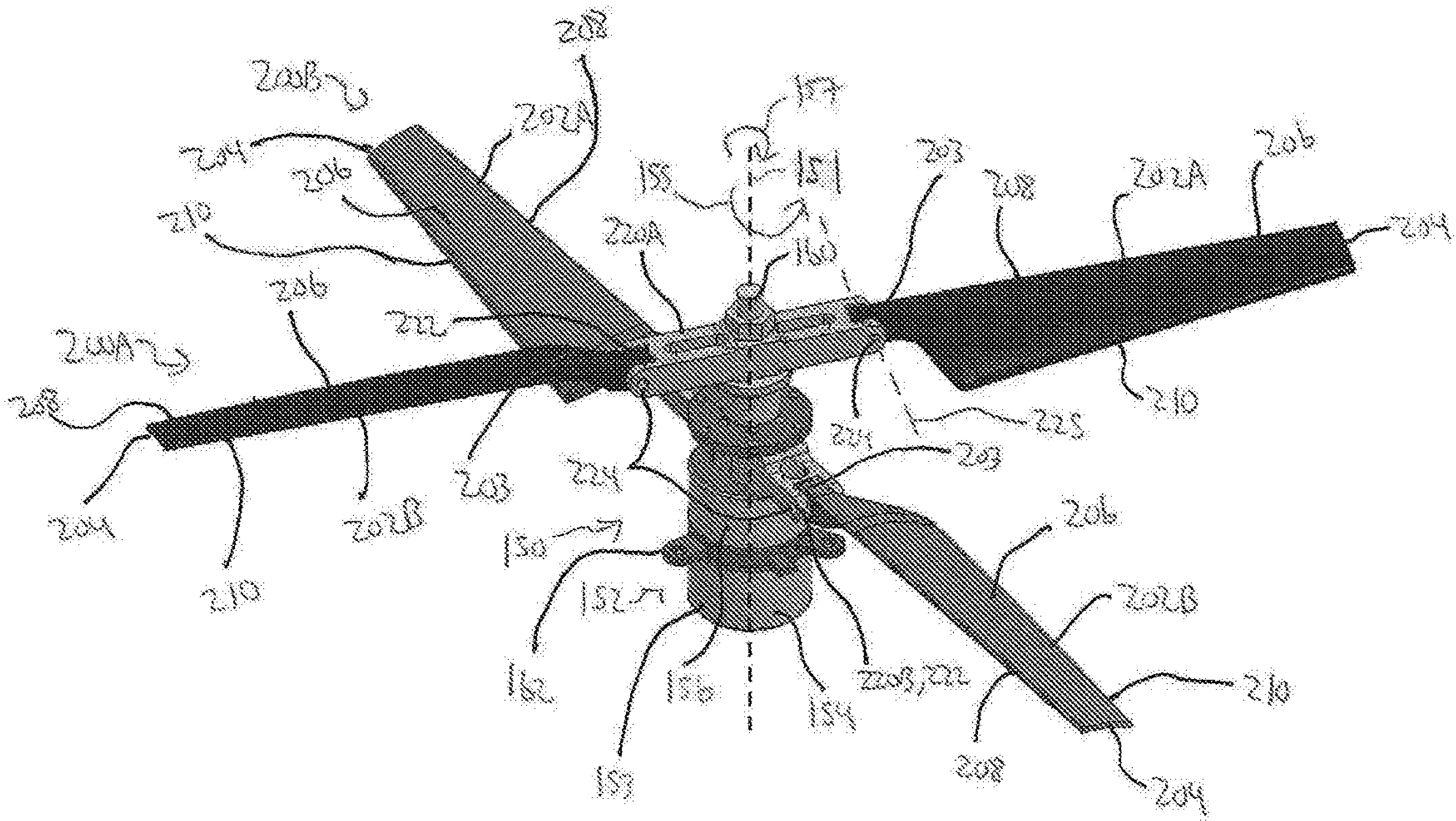
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FIG. 8

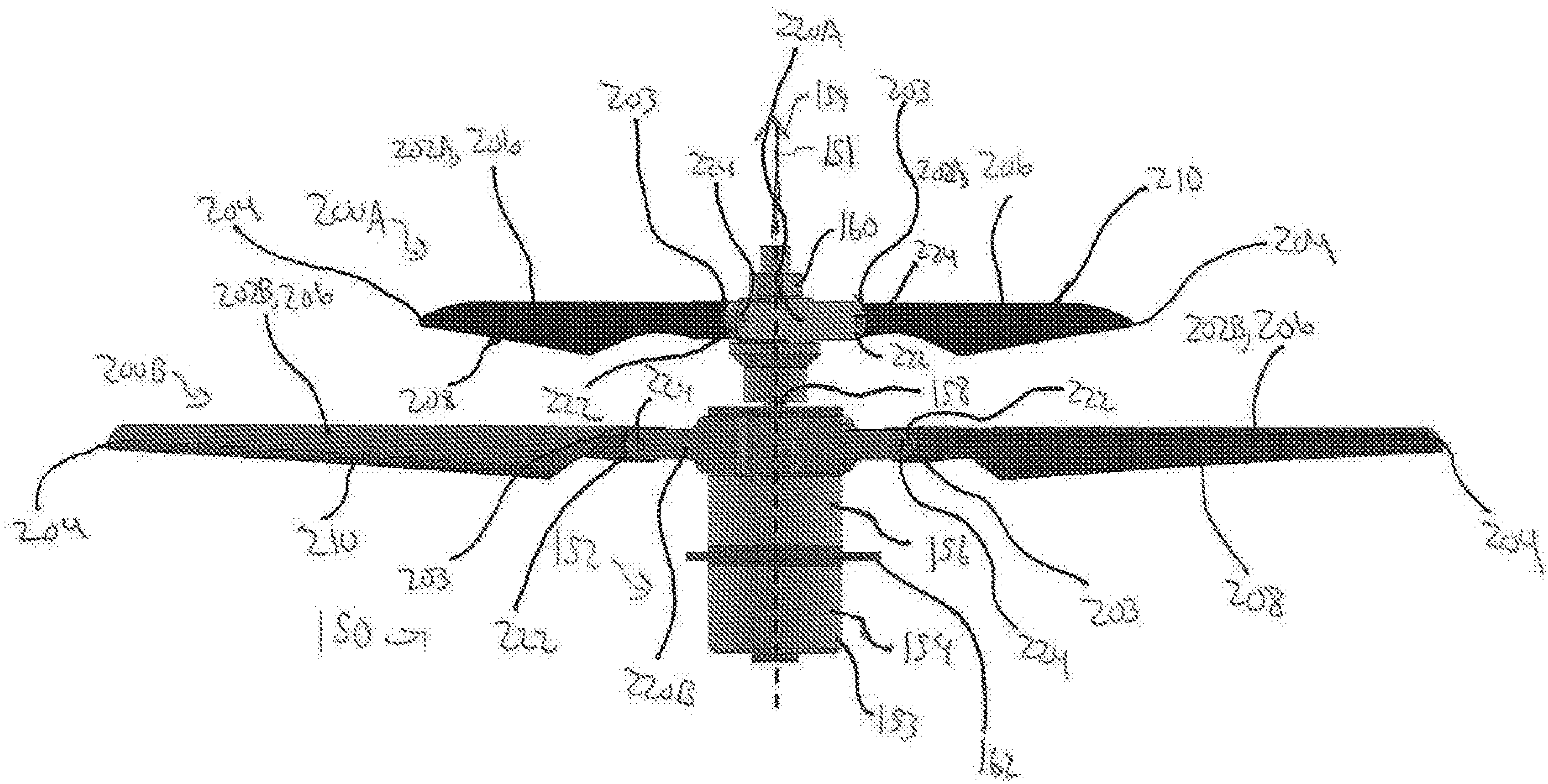
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FIG. 9

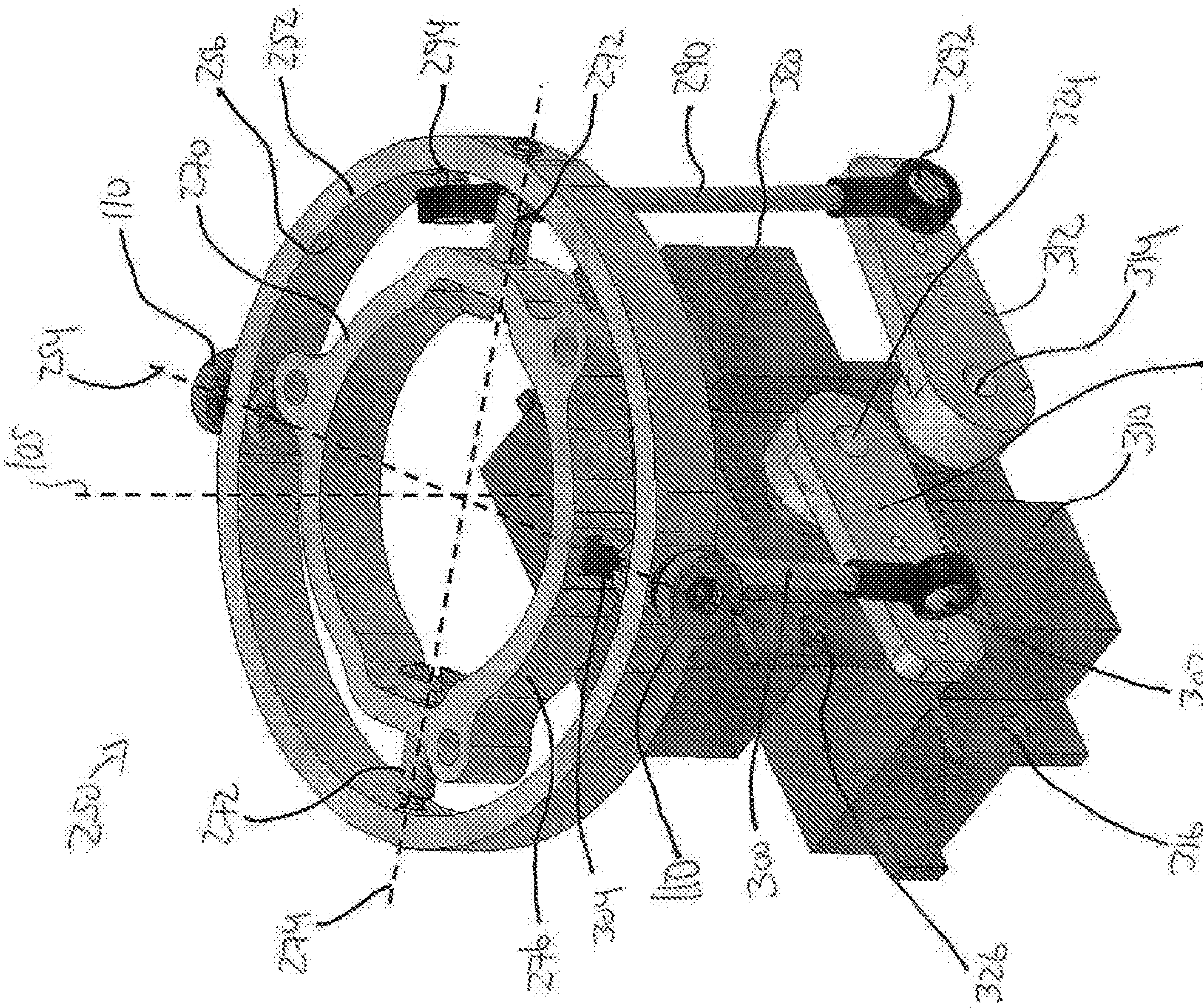

FIG. 11

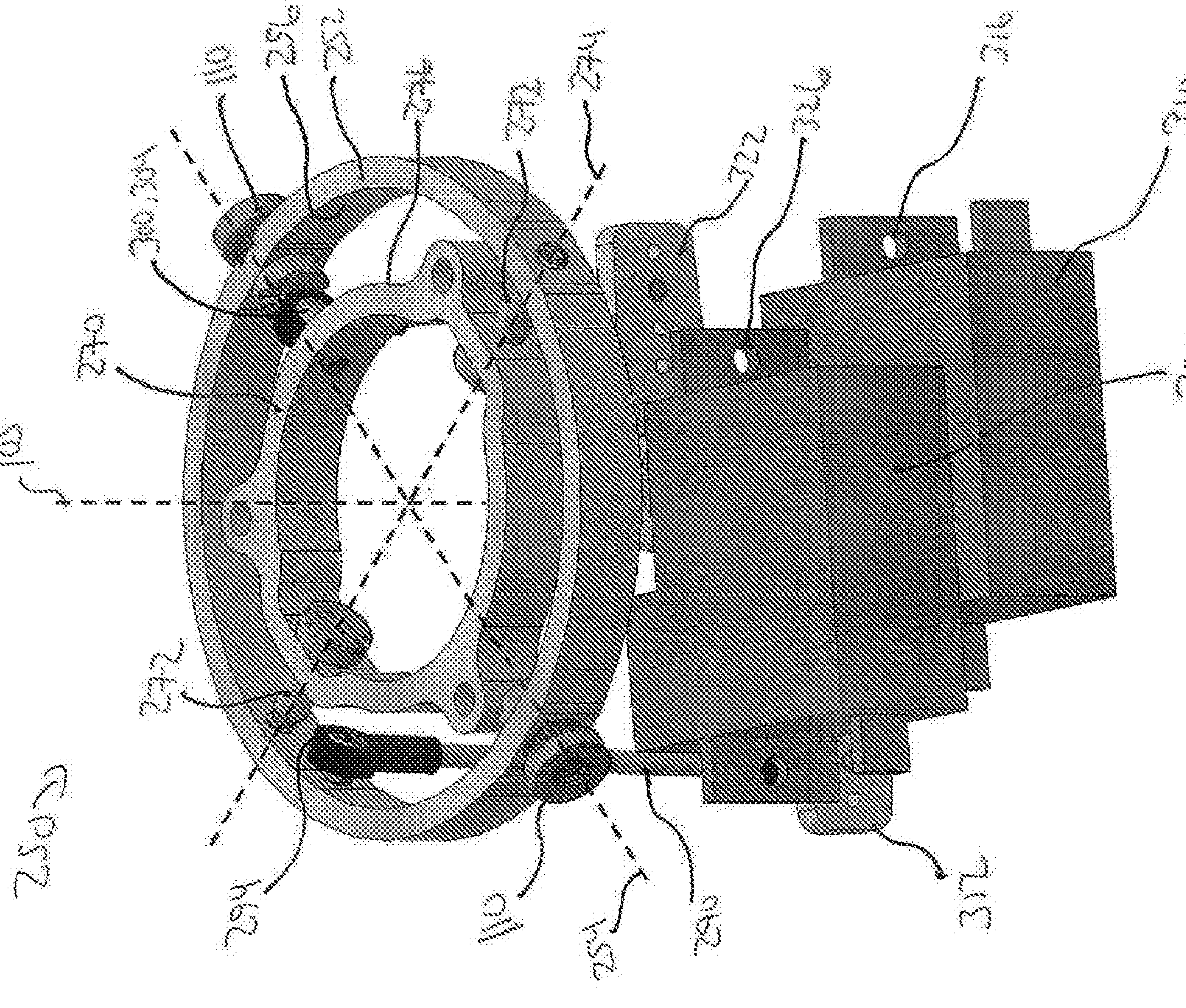

FIG. 10

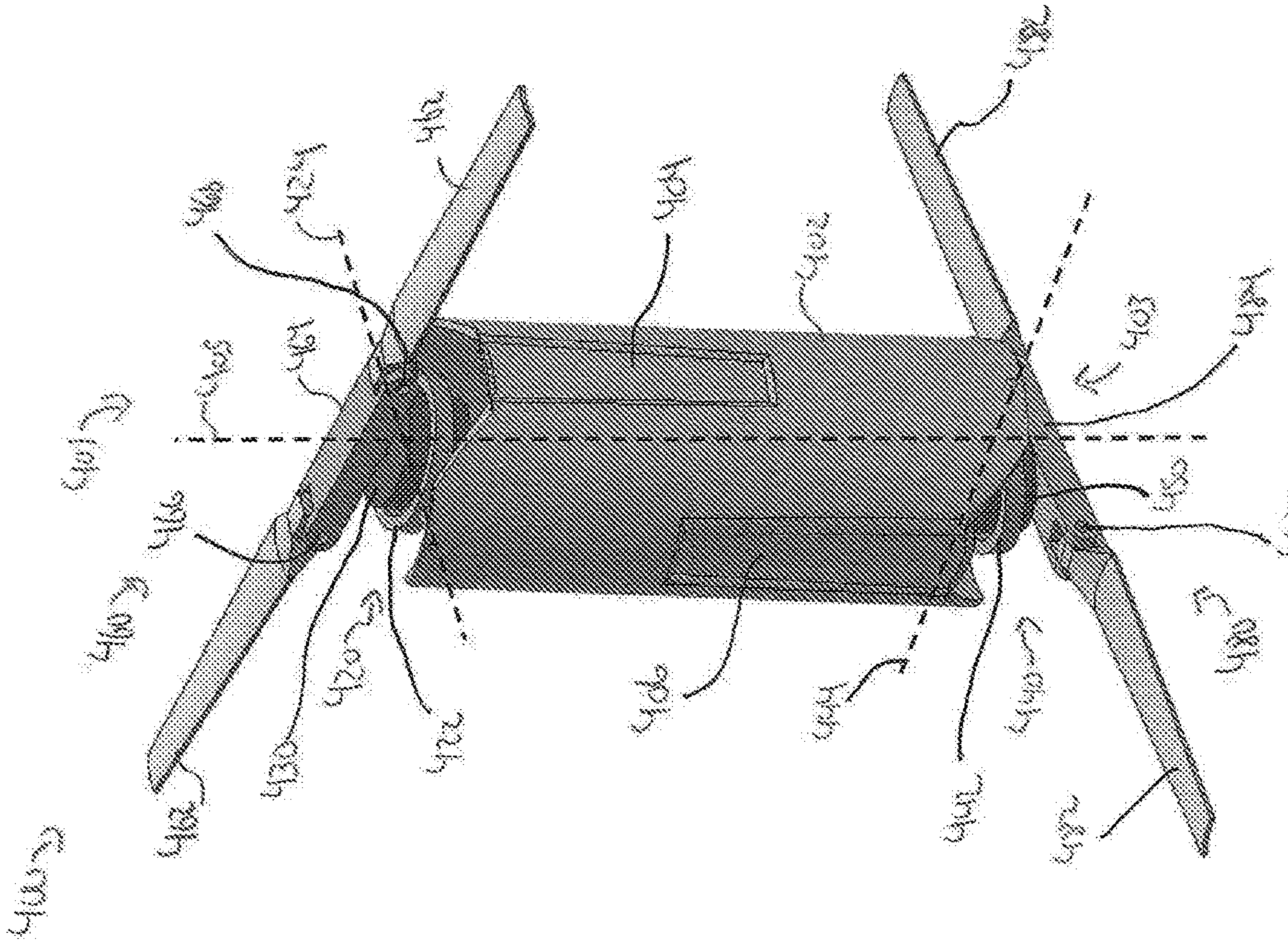

FIG. 13

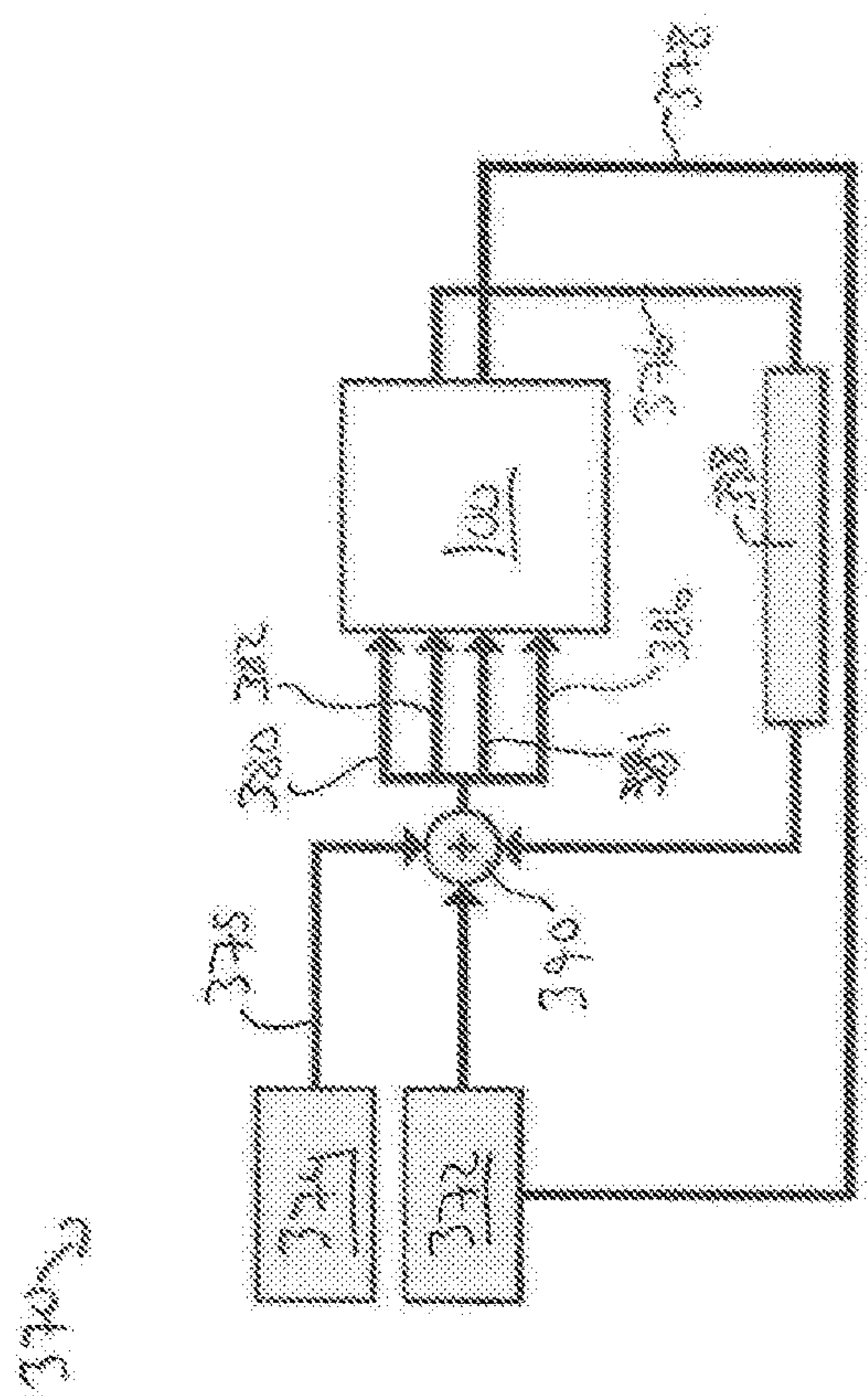

FIG. 12

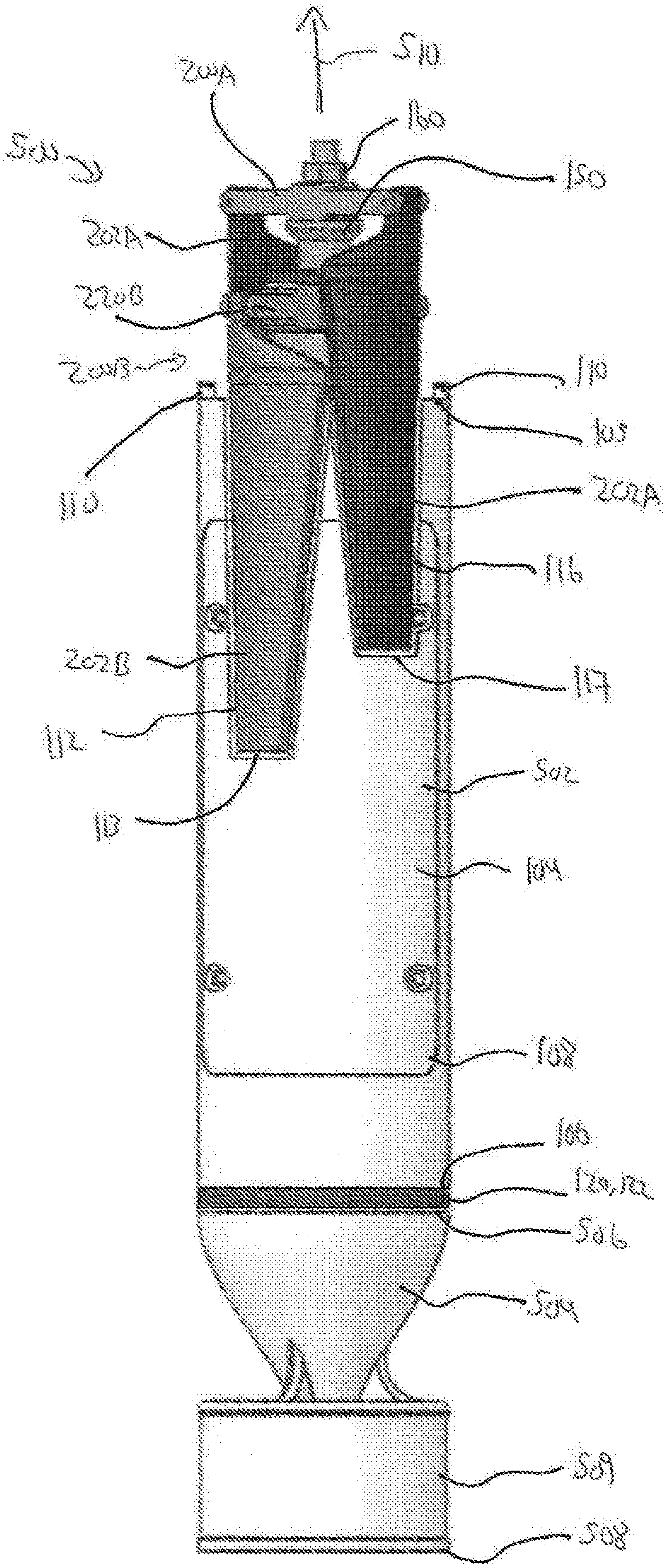
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FIG. 14

ROTARY-WING, HOVER-CAPABLE AIRCRAFT AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a 35 U.S.C. 371 national stage application of PCT/US2020/034396 filed May 22, 2020, and entitled "Rotary-Wing, Hover-Capable Aircraft and Methods", which claims benefit of U.S. provisional patent application No. 62/852,906 filed May 24, 2019, and entitled "Air Launched Hover-Capable Rotary-Wing Aircraft," both of which are hereby incorporated herein by reference in their entirety.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable.

BACKGROUND

Hover-capable, rotary-wing unmanned aircraft, including rotary wing micro air vehicles (MAVs), which rely on the rotation of one or more propellers thereof may have a variety of applications in intelligence, surveillance, reconnaissance (ISR), and search and rescue missions. Hover-capable, rotary-wing aircraft may be electrically powered via one or more batteries carried by the aircraft. In at least some applications, hover-capable, rotary-wing aircraft may have greater power requirements than fixed-wing, non-hover-capable aircraft of a similar size. The power requirements of hover-capable, rotary-wing aircraft may, in at least some applications, may limit the endurance, operating altitude, and/or operating range of the hover-capable, rotary-wing aircraft, thereby limiting the effectiveness of the aircraft.

BRIEF SUMMARY OF THE DISCLOSURE

An embodiment of a projectile-launched aircraft system comprises a projectile launcher comprising a triggering mechanism, a rotary-wing, hover-capable aircraft comprising a rotor assembly that comprises at least one rotor blade, wherein the rotor blade comprises a stowed configuration and a deployed configuration that is circumferentially spaced from the stowed configuration about a pivot axis, wherein, upon actuation of the triggering mechanism, the projectile launcher is configured to launch the aircraft along a flightpath. In some embodiments, the projectile launcher comprises a barrel configured to receive the aircraft and a cartridge comprising a propellant, and wherein the triggering mechanism is configured to initiate the propellant to launch the aircraft from the barrel. In some embodiments, the flightpath comprises at least one of a vertical flightpath and a ballistic flightpath. In certain embodiments, the aircraft comprises a motor configured to rotate the rotor blade and a control system configured to operate the motor to hover the aircraft at a deployment location that is spaced from the projectile launcher. In certain embodiments, the aircraft comprises an airframe comprising an outer surface comprising at least one first recess formed therein, wherein the first rotor blade is at least partially received in the first recess of the airframe when in the stowed configuration. In some embodiments, the aircraft comprises at least one second rotor blade that is spaced along a longitudinal axis of the aircraft from the first rotor blade, wherein the outer surface of the airframe comprises at least one second recess formed therein, and wherein the second rotor blade comprises a stowed configuration and a deployed configuration that is circumferentially spaced from the stowed configuration about a second pivot axis, and wherein the second rotor blade is at least partially received in the second recess of the airframe when in the stowed configuration. In some embodiments, the aircraft comprises a first gimbal pivotably coupled to the airframe whereby the first gimbal is permitted to pivot relative to the airframe about a first axis, wherein the first rotor blade is coupled to the first gimbal and is permitted to pivot about the first axis relative to the airframe. In certain embodiments, the aircraft comprises a second gimbal pivotably coupled to the airframe whereby the second gimbal is permitted to pivot relative to the airframe about a second axis that extends orthogonally to the first axis, wherein at least one of the first rotor assembly and the second rotor blade is coupled to the second gimbal and is permitted to pivot about the second axis relative to the airframe. In some embodiments, the aircraft comprises a motor assembly configured to rotate the first rotor blade and the second rotor blade, a first servo configured to adjust a position of the first gimbal about the first axis, a second servo configured to adjust a position of the second gimbal about the second axis, and a control system configured to operate the first servo to control a pitch of the aircraft, operate the second servo to control a roll of the aircraft, and to operate the motor assembly to control a yaw of the aircraft.

An embodiment of a rotary-wing, hover-capable aircraft comprises an airframe comprising an outer surface that comprises at least one first recess formed therein, a first rotor assembly rotatably coupled to the airframe and comprising at least one first rotor blade, wherein the first rotor blade comprises a stowed configuration and a deployed configuration that is circumferentially spaced from the stowed configuration about a first pivot axis, and wherein the first rotor blade is at least partially received in the first recess of the airframe when in the stowed configuration. In some embodiments, the aircraft further comprises a second rotor assembly rotatably coupled to the airframe and comprising at least one second rotor blade, wherein the second rotor assembly is spaced along a longitudinal axis of the aircraft from the first rotor assembly, wherein the outer surface of the airframe comprises at least one second recess formed therein, and wherein the second rotor blade comprises a stowed configuration and a deployed configuration that is circumferentially spaced from the stowed configuration about a second pivot axis, and wherein the second rotor blade is at least partially received in the second recess of the airframe when in the stowed configuration. In some embodiments, the aircraft further comprises a first motor configured to rotate the first rotor blade in a first rotational direction, and a second motor configured to rotate the second rotor blade in a second rotational direction opposite the first rotational direction. In certain embodiments, the aircraft further comprises a first gimbal pivotably coupled to the airframe whereby the first gimbal is permitted to pivot relative to the airframe about a first axis, wherein the first rotor assembly is coupled to the first gimbal and is permitted to pivot about the first axis relative to the airframe. In certain embodiments, the aircraft further comprises a second gimbal pivotably coupled to the airframe whereby the second gimbal is permitted to pivot relative to the airframe about a second axis that extends orthogonally to the first axis, wherein at least one of the first rotor assembly and the second rotor assembly is coupled to the second gimbal and is permitted to pivot about the second axis relative to the airframe. In some embodiments, the second gimbal is positioned radially within the first gimbal and is configured to pivot about both the first axis and the second axis relative to the airframe, and wherein the first rotor assembly is coupled to the second gimbal. In some embodiments, the aircraft further comprises a motor assembly configured to rotate the first rotor blade and the second rotor blade, a first servo configured to adjust a position of the first gimbal about the first axis, a second servo configured to adjust a position of the second gimbal about the second axis, and a control system configured to operate the first servo to control a pitch of the aircraft, operate the second servo to control a roll of the aircraft, and to operate the motor assembly to control a yaw of the aircraft. In certain embodiments, the aircraft comprises a first rotor assembly that comprises a plurality of circumferentially spaced first rotor blades and a rotor hub centrally positioned between the plurality of first rotor blades, and wherein a radially inner end of each first rotor blade couples to the rotor hub at one of a plurality of hinges.

An embodiment of a method for directing a rotary-wing, hover-capable aircraft along a flightpath comprises (a) launching the aircraft from a projectile launcher positioned at a launch location, (b) actuating a rotor blade of the aircraft from a stowed configuration and a deployed configuration that is circumferentially spaced from the stowed configuration about a pivot axis, and (c) hovering the aircraft at a deployment location that is spaced from the launch location. In some embodiments, (b) comprises operating a motor assembly of the aircraft to rotate the rotor blade about a rotational axis. In some embodiments, the first rotor blade is received in a recess formed in an outer surface of an airframe of the aircraft when the first rotor blade is in the stowed configuration.

BRIEF DESCRIPTION OF THE DRAWINGS

For a detailed description of exemplary embodiments of the disclosure, reference will now be made to the accompanying drawings in which:

FIG. **1** is a schematic of a projectile-launched aircraft system according to some embodiments;

FIGS. **2**, **3** are side views of a rotary-wing, hover-capable aircraft of the system of FIG. **1** according to some embodiments;

FIGS. **4**, **5** are perspective views of the aircraft of FIGS. **2**, **3**;

FIG. **6** is a side view of the aircraft of FIGS. **2**, **3** opposite the side view shown in FIG. **2**;

FIG. **7** is a top view of the aircraft of FIGS. **2**, **3**;

FIG. **8** is a perspective view of a powertrain, a first rotor assembly, and a second rotor assembly of the aircraft of FIGS. **2**, **3** according to some embodiments;

FIG. **9** is a side view of the powertrain, first rotor assembly, and second rotor assembly of FIG. **8**;

FIGS. **10**, **11** are perspective views of a thrust vectoring assembly of the aircraft of FIGS. **2**, **3** according to some embodiments;

FIG. **12** is a flowchart of an embodiment of a feedback control mechanism of the aircraft of FIGS. **2**, **3** according to some embodiments;

FIGS. **13**, **14** are perspective views of other rotary-wing, hover-capable aircraft of the system of FIG. **1** according to some embodiments.

DETAILED DESCRIPTION OF THE DISCLOSED EMBODIMENTS

The following discussion is directed to various exemplary embodiments. However, one skilled in the art will understand that the examples disclosed herein have broad application, and that the discussion of any embodiment is meant only to be exemplary of that embodiment, and not intended to suggest that the scope of the disclosure, including the claims, is limited to that embodiment.

Certain terms are used throughout the following description and claims to refer to particular features or components. As one skilled in the art will appreciate, different persons may refer to the same feature or component by different names. This document does not intend to distinguish between components or features that differ in name but not function. The drawing figures are not necessarily to scale. Certain features and components herein may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in interest of clarity and conciseness.

In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to . . . " Also, the term "couple" or "couples" is intended to mean either an indirect or direct connection. Thus, if a first device couples to a second device, that connection may be through a direct connection, or through an indirect connection via other devices, components, and connections. In addition, as used herein, the terms "axial" and "axially" generally mean along or parallel to a central axis (e.g., central axis of a body or a port), while the terms "radial" and "radially" generally mean perpendicular to the central axis. For instance, an axial distance refers to a distance measured along or parallel to the central axis, and a radial distance means a distance measured perpendicular to the central axis.

As described above, in at least some applications, hover-capable, rotary-wing aircraft may have greater power requirements than fixed-wing, non-hover-capable aircraft of a similar size. The requirements of hover-capable, rotary-wing aircraft may, in at least some applications, limit the endurance, operating altitude, and/or operating range of the hover-capable, rotary-wing aircraft. Additionally, the power requirements of the hover-capable, rotary-wing aircraft may require the use of a battery of increased size which may limit the performance of the aircraft and reduce the amount of payload (e.g., sensors and other equipment) which the aircraft may carry.

Embodiments disclosed herein include hover-capable, rotary-wing aircraft which may be launched as a projectile from a launcher positioned a first or launcher location to a second or deployment location distal the launcher location. For instance, the deployment location may be at a horizontal distance along the ground relative to the first location as well as at a different altitude than the launcher location. In this manner, the aircraft may utilize the energy imparted to the aircraft from the launcher to arrive at the deployment location without requiring the operation of one or more propellers of the aircraft. In some embodiments, the aircraft may be launched along a parabolic or ballistic trajectory or flightpath by the launcher towards the deployment location, and may only deploy one or more propellers of the aircraft once the aircraft is either within the vicinity of the deployment location or positioned at the deployment location. In other embodiments, the aircraft may be launched vertically upwards by the launcher towards the deployment location (positioned at an altitude above the launcher location), and may only deploy one or more propellers of the aircraft once the aircraft is either within the vicinity of the deployment location or positioned at the deployment location.

Referring to FIG. **1**, an embodiment of a projectile-launched aircraft system **10** is shown in FIG. **1**. In the embodiment of FIG. **1**, system **10** generally includes a projectile launcher **12** and an unmanned hover-capable, rotary-wing aircraft **50** launchable from the projectile launcher **12**. As used herein, the term "hover-capable" describes aircraft capable of hovering flight. Projectile launcher **12** may generally comprise a generally cylindrical firing tube or barrel **14**, a cartridge **16**, and a triggering mechanism or trigger **18**.

Barrel **14** of projectile launcher **12** is configured to slidably receive aircraft **50** and, in some embodiments, may have an inner diameter of less than 100 millimeters (mm) (e.g., between approximately 40 mm and 60 mm). Cartridge **16** may also be received within barrel **14** of projectile launcher **12** between aircraft **50** and an enclosed end **15** of barrel **14**. Cartridge **16** may comprise a propellant and an ignition device or primer configured to initiate the propellant in response to receiving a firing signal. In some embodiments, the propellant and primer may each be enclosed within an outer case. The propellant may comprise a material configured to rapidly create pressurized gas to launch aircraft **50** from projectile launcher along an airborne parabolic or ballistic trajectory or flightpath (indicated by arrows **30** in FIG. **1**). In some embodiments, the propellant of cartridge **16** may comprise a combustible or explosive material. Trigger **18** of projectile launcher may selectably issue a firing signal to cartridge **16** in response to actuation by a user of projectile launcher **12**. For example, upon actuation, trigger **18** may percussively actuate the primer of cartridge **16** to ignite a propellant of cartridge **16**.

As described above, projectile launcher **12** is generally configured to convert energy (e.g., chemical energy) stored within cartridge **16** into kinetic energy of aircraft **50**. Although in the embodiment shown in FIG. **1** a cartridge **16** is used as a source of energy that may be converted into kinetic energy of aircraft **50**, in other embodiments, the source of energy which may be converted into kinetic energy of aircraft **50** may vary. For instance, pneumatic, hydraulic, and/or electrical sources of energy may be utilized for launching aircraft **50**. Further, in some embodiments, aircraft **50** may not be launched from a cylindrical tube such as the barrel **14** of projectile launcher **12**. For example, aircraft **50** may be launched along an airborne flightpath (e.g., ballistic flightpath **30** shown in FIG. **1**) using a rail, catapult, or other mechanism.

Aircraft **50** of system **10** may generally include a body or airframe **52** and one or more rotors **54** rotatably coupled to airframe **52**. Rotors **54** may each be disposed in a stowed configuration when aircraft **50** is positioned within the barrel **14** of projectile launcher **12**. In the stowed configuration, each rotor **54** may extend substantially parallel a longitudinal axis of aircraft **50** and positioned against an outer surface of airframe **52** in order to minimize a maximum outer diameter of aircraft **50** and thereby permit aircraft **50** to be loaded into barrel **14**. As will be described further herein, rotors **54** may be actuated from the stowed configuration to a deployed configuration. In the deployed configuration, rotors **54** may be rotated by a motor (not shown in FIG. **1**) of aircraft **50** to allow aircraft **50** to hover and perform one or more functions at a deployment location **26** distal the projectile launcher **12**.

In some embodiments, the barrel **14** of projectile launcher **12** may be positioned at a non-zero, acute angle **22** relative to the ground **2** to achieve the ballistic flightpath **30** of aircraft **50** following the actuation of the trigger **18** of projectile launcher **12**. For example, in some embodiments, projectile launcher **12** may be light enough to manually aim by a user of projectile launcher **12**; however, the manner in which projectile launcher **12** may be positioned may vary in different applications. In this embodiment, the barrel **14** of projectile launcher **12** is positioned at acute angle **22** relative to the surface **2** to launch aircraft **50** from a first or launch location **24**, along ballistic flightpath **30**, to the second or deployment location **26** distal the launch location **24**.

The deployment location **26** at which aircraft **50** is positioned after being launched from projectile launcher **12** may be spaced a horizontal distance **28** along the ground **2** relative to the launch location **24**. Additionally, the deployment location **26** of aircraft **50** may be spaced a vertical distance or altitude **32** relative to the launch location **24**. Thus, the energy transferred to aircraft **50** from projectile launcher **12** may be utilized to position aircraft **50** at a desired horizontal position along surface **2** and at a desired vertical distance or altitude from surface **2**. By utilizing projectile launcher **12** as an energy source for displacing aircraft **50** from the launch location **24** to the deployment location **26**, energy stored within aircraft **50** (e.g., batteries, fuel) need only be utilized once the aircraft **50** is travelling towards or has arrived at the deployment location **26** for performing one or more functions at the deployment location **26** (e.g., surveillance, etc.). In other words, by utilizing projectile launcher **12** to impart kinetic energy to aircraft **50**, the amount of energy stored within aircraft **50** needed for positioning aircraft **50** at the deployment location **26** may be minimized, thereby maximizing the amount of energy stored within aircraft **50** which may be utilized for performing one or more functions at the deployment location **26**. For instance, by utilizing projectile launcher **12** for transporting aircraft **50** to the deployment location **26**, a payload of aircraft **50** and/or the amount of time aircraft **50** may loiter at operating position **26** may be increased.

Although in this embodiment barrel **14** of projectile launcher **12** is positioned at acute angle **22** relative to the ground **2** to produce a ballistic flightpath **30** of aircraft **50**, in other embodiments, the position of barrel **14** may be altered to produce different trajectories of aircraft **50**. For example, barrel **14** of projectile launcher **12** may be positioned at a substantially orthogonal or ninety degree angle relative to the ground **2** to launch aircraft **50** along a vertical flightpath to an operating position that is vertically spaced from projectile launcher **12** but it has minimal or zero horizontal spacing along ground **2** relative to projectile launcher **12**.

In his embodiment, the flight of aircraft **50** along ballistic flightpath **30** may include one or more stages. Particularly, the ballistic flightpath **30** of aircraft **50** may include an ascent or projectile phase **34**, a descent phase **36** following the projectile phase **34**, and a hover phase **38** following the descent phase **36**. In some embodiments, during the projectile phase **34** of ballistic flightpath **30** the aircraft **50** is initially launched from the barrel of projectile launcher **12** following the actuation of trigger **18**. During the projectile phase **34**, aircraft **50** ascends or travels vertically upwards away from ground **2** along the ballistic flightpath **30** in response to a force applied to the aircraft **50** from the ignition of cartridge **16**. Additionally, in some embodiments, a protective load transfer cap or cover **56** positioned between aircraft **50** and cartridge **16** within the barrel **14** of projectile launcher **12** to protect components of aircraft **50** (e.g., rotors **54**) from the shock following the ignition of cartridge **16**. Load transfer cap **56** may fall away from aircraft **50** at some point during the projectile phase **34** of ballistic flightpath **30**.

Aircraft **50** may reach the apex of the ballistic flightpath **30** at the end of the projectile phase **34** thereof and begin the descent phase **36**. In the descent phase **36** of ballistic flightpath **30**, aircraft **50** may deploy one or more of the rotors **54** of aircraft **50** prior to reaching the hover phase **38** of ballistic flightpath **30**. In some embodiments, a motor of aircraft **50** may rotate one or more of the rotors **54** whereby the centripetal force applied to the one or more rotating rotors **50** may force the rotors radially outwards (relative a longitudinal axis of aircraft **50**) from the stowed configuration into a deployed configuration. In other embodiments, different mechanisms may be used to deploy one or more rotors **54** of aircraft **50** during the descent phase. For instance, one or more dedicated actuators of aircraft **50** may be used to deploy rotors **54**.

Once rotors **54** of aircraft **50** are disposed in the deployed configuration, a rotational speed of each rotor **54** may be increased whereby thrust sufficient for aircraft **50** to hover above ground **2** and allow aircraft **50** to enter the hover phase **38** of ballistic flightpath **30**. In this embodiment, thrust generated by rotors **54** may be used to slow or terminate the descent of aircraft **50** towards the ground **2** such that aircraft **50** may hover and maintain a desired altitude above ground **2**. In some embodiments, aircraft **50** may include a device configured to induce drag (e.g., a parachute, etc.) during the descent phase **36** to assist in terminating the descent of aircraft **50**. Additionally, in some embodiments, aircraft **50** may include a stabilizer configured to assist in stabilizing the trajectory of aircraft **50** over ballistic flightpath **30**. Aircraft **50** is located at operating position **26** upon reaching the hover phase **38** of ballistic flightpath **30** and may comment performing one or more functions at location **26**. For example, aircraft **50** may comprise a payload including one or more sensors for acquiring data and performing ISR operations at the deployment location **26**.

During the travel of aircraft **50** along ballistic flightpath **30**, the motor of aircraft **50** may only be operated during the descent and hovering stages **36**, **38**. Therefore, the motor of aircraft **50** need not be operated during the ascent phase **34** of flightpath **30** and thus aircraft **50** need only rely on the energy imparted to aircraft **50** from projectile launcher **12** to reach the apex or maximum altitude of ballistic flightpath **30**. In this manner, the amount of energy expended by the motor of aircraft **50** prior to entering the hovering stage **38** at the deployment location **26** may be minimized.

Referring to FIGS. **2**-**7**, an embodiment of an unmanned hover-capable, rotary-wing aircraft **100** is shown in FIGS. **2**-**7**. Aircraft **100** may be utilized in projectile-launched aircraft systems similar to the system **10** described above and shown in FIG. **1**. Thus, aircraft **100** may be launched from a projectile launcher (e.g., projectile launcher **12**) at a launch position, travel along an airborne flightpath (e.g., a ballistic flightpath, a vertical flightpath, etc.), and arrive at a deployment position distal the launch position to perform one or more functions (e.g., ISR, etc.).

In some embodiments, aircraft **100** may have a longitudinal first end **101**, a longitudinal second end **103** opposite first end **101**, a central longitudinal axis **105** and may generally include a support structure or airframe **102**, a powertrain **150**, a pair of counter-rotating rotors or rotor assemblies **200**A, **200**B, a protective load transfer cap or cover **240**, an actuator or thrust vectoring assembly **250**, and a control system **350**.

In some embodiments, aircraft **100** is configured to be launched along a ballistic flightpath (e.g., flightpath **30** shown in FIG. **1**) from a projectile launcher (e.g., projectile launcher **12** shown in FIG. **1**). Particularly, within a launch tube of the projectile launcher, load transfer cap **240** may be positioned between rotor assemblies **200**A, **200**B (each located at the first end **101** of aircraft **100**) and a cartridge (e.g., cartridge **16** of FIG. **1**) of the projectile launcher. Load transfer cap **240** may include a longitudinal first end **242**, a longitudinal second end **244** opposite first end **242**, the first end **242** being positionable adjacent the cartridge when aircraft **100** is loaded in the projectile launcher. Load transfer cap **240** may protect components of aircraft **100** (e.g., rotor assemblies **200**A, **200**B) from shock generated by the initiation of the cartridge of the projectile launcher. Additionally, load transfer cap **240** may also include a fin or stabilizer **246** proximal first end **242** for stabilizing the flight of aircraft **100** following the launch of aircraft **100** from the projectile launcher; however, in other embodiments, load transfer cap **240** may not include stabilizer **246**.

In some embodiments, airframe **102** may provide structural support to and anchor the components of aircraft **100** (e.g., rotor assemblies **200**A, **200**B, thrust vectoring assembly **250**, control system **350**, etc.) and may generally include a generally cylindrical body **104** (body **104** is hidden from view in FIG. **5**) and a nose **130** coupled to the body **104**. In some embodiments, components of the airframe **102** (e.g., body **104**, nose **130**) may be fabricated from acrylonitrile butadiene styrene (ABS) plastic; however, in other embodiments, the materials comprising airframe **102** may vary.

Body **104** may comprise a central or longitudinal axis **107** and have a longitudinal first end **105** and a longitudinal second end **106** opposite the first end **105**, and a generally cylindrical outer surface **108** extending between ends **105**, **106**. In some embodiments, outer surface **108** of body **104** may be smoothed or polished to provide a smooth contact surface between body **104** and an inner surface of a barrel of a projectile launcher from which aircraft **100** is launched. One or more components of aircraft **100** (e.g., thrust vectoring assembly **250**, control system **350**, etc.) may be at least partially disposed within a central passage formed within body **104**. In some embodiments, body **104** may include a removable panel to allow access to components of aircraft **100** stored within body **104**. Body **104** may comprise a pair of circumferentially spaced pivot joints or connectors **110** located at the first end **105** thereof. As will be described further herein, at least a portion of the thrust vector assembly **200** may pivotably couple with body **104** via the pivot joints **110**. In this embodiment, pivot joints **110** are spaced approximately 180 degrees apart about central axis **105** of aircraft **100**; however, in other embodiments, the circumferential spacing of pivot joints **110** may vary.

In some embodiments, the outer surface **108** of body **104** may include a pair of first rotor recesses **112** and a pair of second rotor recesses **116**. Particularly, each rotor recess **112**, **116** is formed within outer surface **108** of body **104** such that the outer diameter of body **104** defined by outer surface **108** is reduced along the portions of outer surface **108** covered by recesses **112**, **116**. Additionally, each recess **112**, **116** extends from first end **105** of body **104** to a terminal end **113**, **117**, respectively, which is spaced from the second end **106** of body **104**. In this embodiment, the first rotor recesses **112** are spaced approximately 180 degrees apart about central axis **105**. Similarly, the second rotor recesses **116** are spaced approximately 180 degrees apart about central axis **105**; however, in other embodiments, the circumferential spacing of the pair of first rotor recesses **112** and the circumferential spacing between the pair of second rotor recesses **116** may vary. Additionally, each second rotor recess **116** may be circumferentially spaced from each first rotor recess **112**.

As will be discussed further herein, each first rotor recess **112** is configured to receive a rotor blade **202**A of the first rotor assembly **200**A while each second rotor recess **116** is configured to receive a rotor blade **202**B of the second rotor assembly **200**B whereby each rotor blade **202**A, **202**B of the rotor assemblies **200**A, **200**B may be positioned substantially flush with body **104** when each rotor assembly **200**A, **200**B is disposed in a stowed configuration (shown in FIG. **3**). In some embodiments, an outer diameter extending between an outer surface **206** of each separate pair of rotor blades **202**A, **202**B (e.g., a diameter extending between the pair of rotor blades **202**A, **202**B of first rotor assembly **200**A) is equal to or less than a maximum outer diameter of the outer surface **108** of body **104**. In this manner, rotor recesses **112**, **116** of body **104** may serve to minimize a maximum outer diameter of aircraft **100** and protect the rotor blades **202**A, **202**B of each rotor assembly **200**A, **200**B, respectively during the launch of aircraft **100** from a projectile launcher (e.g., projectile launcher **12** shown in FIG. **1**).

Airframe **102** may additionally include a power supply mount **120** coupled between body **104** and nose **130**, where power supply mount **120** is generally configured to provide structural support to a power supply **140** of aircraft **100**. In this embodiment, power supply mount **120** may comprise an annular flange **122** and a rectangular cage or holder **124** extending from flange **122**. The power supply **140** of aircraft **100** may be received within holder **124**. Particularly, relative movement between power supply **140** and airframe **102** may be restricted when power supply **140** is received within holder **124** and power supply mount **120** is coupled to the body **104** and nose **130** of airframe **102**.

In this embodiment, power supply **140** of aircraft **100** comprises an electrical battery pack configured to provide electrical power to components of aircraft **100**, including powertrain **150**, thrust vectoring assembly **250**, and control system **350**. In some embodiments, power supply **140** may comprise a lithium polymer battery configured to output approximately 1,000 milliamp hours (mAh) and 1,500 mAh to allow aircraft **100** to hover for periods in excess of ten minutes; however, in other embodiments, the configuration of power supply **140** may vary. For example, in other embodiments, power supply **140** may comprise fuel storing chemical energy for powering the operation of aircraft **100** rather than a battery pack storing electrical energy.

The nose **130** of airframe **102** comprises a longitudinal first end **132** and a longitudinal second end **134** opposite the first end **132** and which defines the second end **103** of aircraft **100**. In some embodiments, the flange **122** of the power supply mount **120** may be coupled between the first end **132** of the nose **130** and the second end **106** of the body **104** of airframe **102**. Nose **130** may include a hemispherical outer surface **136** to reduce the drag of aircraft **100** as it travels along a ballistic flightpath; however, the configuration of nose **130** may vary in other embodiments.

Referring to FIGS. **8**, **9**, views of the powertrain **150** of aircraft **100** are shown. In some embodiments, powertrain **150** may generally include a counter-rotating motor assembly **152** that includes a first motor **154** and a second motor **156**. Motors **154**, **156** of motor assembly **152** may be electrically connected with and powered by the power supply **140** of aircraft **100**. As will be described further herein, control system **350** of aircraft **100** may independently control the operation of each motor **154**, **156**. First motor **154** is coupled to first rotor assembly **200**A via a first or inner driveshaft **158** which extends through both second motor **156** and second rotor assembly **200**B. Second motor **156** is coupled to second rotor assembly **200**B via a second or outer driveshaft (hidden from view in FIGS. **8**, **9**) which extends annularly about the inner driveshaft **158**. A fastener or nut **160** may secure rotor assemblies **200**A, **200**B to the motors **154**, **156** of motor assembly **152**. Additionally, motor assembly **150** may comprise an annular mount **162** positioned about an outer surface **153** of motor assembly **152**. As will be described further herein, mount **162** of motor assembly **152** may pivotably couple with motor assembly **152** to permit motor assembly **152** (along with rotor assemblies **200**A, **200**B coupled thereto) to pivot about a plurality of orthogonal axes relative to the airframe **102** of aircraft **100**.

In some embodiments, motors **154**, **156** may each comprise brushless electric motors separated by bearings (not shown in FIGS. **8**, **9**) which permit rotors of motors **154**, **156** to rotate in opposite directions. Additionally, in some embodiments, motor assembly **152** may collectively produce approximately between four and ten Newtons (N) of thrust; however, in other embodiments, the configuration and performance of motor assembly, as well as the relative positioning of motors **154**, **156** and rotor assemblies **200**A, **2006**, may vary.

In the configuration described above, first motor **154** is configured to rotate first rotor assembly **200**A in a first rotational direction (indicated by arrow **155** in FIG. **8**) about a rotational axis **151** extending centrally through thrust vectoring assembly **250** while second motor **156** is configured to rotate second rotor assembly **200**B about a second rotational direction (indicated by arrow **157** in FIG. **8**) about the rotational axis **151**, where the second rotational direction **157** is opposite of the first rotational direction **155**. In other words, motor assembly **152** of aircraft **100** is configured to counter-rotate rotor assemblies **200**A, **200**B coaxially about the rotational axis **151**. Although rotor assemblies **200**A, **200**B counter-rotate, the rotor blades **202**A, **202**B of rotor assemblies **200**A, **200**B, respectively, are configured to provide a unified or singular thrust vector (indicated by arrow **159** in FIG. **9**) in response to the counter-rotation of rotor assemblies **200**A, **200**B.

Still referring to FIGS. **8**, **9**, in some embodiments, first rotor assembly **200**A may be spaced along central axis **105** of aircraft **100** from second rotor assembly **200**A. Additionally, first rotor assembly **200**A may comprise a pair of first rotor blades **202**A and a first rotor hub **220**A while second rotor assembly **200**B may comprise a pair of second rotor blades **202**B and a second rotor hub **220**B. In the interest of simplicity, first rotor blades **202**A and first rotor hub **220**A of first rotor assembly **200**A are described in detail below. However, second rotor blades **202**B and second rotor hub **200** of second rotor assembly **200**A may be similar in configuration to first rotor blades **202**A except that second rotor blades **202**B are configured for rotation in the second rotational direction **157** while the first rotor blades **202**A are configured for rotation in the first rotational direction **155**. Additionally, the second rotor hub **220**B of second rotor assembly **200**B may be similar in configuration the first rotor hub **220**A of first rotor assembly **200**A. Thus, rotor blades **202**A, **202**B and rotor hubs **220**A, **220**B include features in common and shared features are labeled similarly.

Each first rotor blade **202**A comprises a radially inner end or root **203**, a radially outer end **204**, the outer surface **206** extending between ends **203**, **204**, a leading edge **208** extending between ends **203**, **204**, and a trailing edge **210** extending between ends **203**, **204**. In some embodiments, each first rotor blade **202**A may have a maximum outer diameter (when in the deployed configuration) of approximately between 200 mm and 250 mm, a thickness of approximately between 1.0 mm and 2.0 mm, a 75% span angle of approximately between 15.0 degrees and 20 degrees, a twist of approximately between 6.5 degrees and 8.0 degrees, and a solidity of approximately between 0.05 and 0.08. Additionally, in some embodiments, each rotor blade **202**A may be manufactured using a rapid prototyping technique using polylactic acid (PLA) or carbon reinforced fiber polymers (CRFP). However, in other embodiments, the configuration and process of manufacturing of each first rotor blade **202**A (as well as each similarly configured second rotor blade **202**B) may vary.

In some embodiments, the first rotor hub **220**A of each rotor assembly **200**A, **200**B comprises a central passage for receiving the inner shaft **158** of motor assembly **152** and a pair of opposed radially outer ends **222**. Each radially outer end **222** of first rotor hub **220**A may comprise a hinge **224** pivotably connected to the radially inner end **203** of one of the first rotor blades **202**A. In this configuration, each first rotor blade **202**A may pivot about a pivot axis **225** (one of which is shown in FIG. **8**) that extends orthogonal central axis **105** of aircraft **100** and which is defined by the hinge **224** coupling the first rotor blade **202**A to the first rotor hub **220**A. Particularly, each first rotor blade **202**A may pivot about pivot axis **225** between a stowed configuration (not shown in FIGS. **8**, **9**) and a deployed configuration (shown in FIGS. **8**, **9**).

In the stowed configuration, a longitudinal axis of each first rotor blade **202**A of the first rotor assembly **200**A may extend along a longitudinal axis which extends substantially parallel with central axis **105** of aircraft **100**. In the deployed configuration, the longitudinal axis of each first rotor blade may extend substantially orthogonal to central axis **105**. In some embodiments, each hinge **224** of first rotor hub **220**A may include a mechanical stop configured to prevent the first rotor blade **202**A attached thereto from pivoting beyond a substantially orthogonal position (relative central axis **105**) when the rotor blade **202**A is actuated from the stowed configuration to the deployed configuration. Additionally, in some embodiments, each first rotor blade **202**A may pivot approximately ninety degrees about pivot axis **225** when the first rotor blade **202**A pivots between the stowed and deployed configurations; however, in other embodiments, the relative positioning of the stowed and deployed configurations of each first rotor blade **202**A may vary.

In some embodiments, each hinge **224** of first rotor hub **220**A is configured to impart enough friction or resistance to pivoting of each first rotor blade **202**A about its respective pivot axis **225** such that first rotor blades **202**A do not flap (e.g., cyclically pivot about its respective pivot axis **225**) during operation of aircraft **100**. In some embodiments, following the launching of aircraft **100** from a projectile launcher, the friction imparted by each hinge **224** of first rotor hub **220**A may maintain each first rotor blade **202**A in the stowed configuration until first motor **154** of motor assembly **152** is actuated (e.g., during the decent phase of the flightpath of aircraft **100**) to rotate in the first rotational direction **155**. In some embodiments, the centripetal force applied to each first rotor blade **202**A in response to the rotation of first rotor assembly **200**A in the first rotational direction **155** overcomes the friction imparted by each hinge **224**, forcing each first rotor blade **202**A radially outwards into the deployed configuration. In other embodiments, an actuator may control the actuation of each first rotor blade **202**A between the stowed and deployed configurations.

Referring to FIGS. **7**, **10**, and **11**, views of the thrust vectoring assembly **250** of aircraft **100** are shown in FIGS. **10**, **11**. Thrust vectoring assembly **250** is generally configured to control an orientation of each rotor assembly **200**A, **200**B relative airframe **102** to thereby selectably orient or control a vector of the thrust produced by rotor assemblies **200**A, **200**B. The hovering flight of aircraft **100** may be at least partially controlled by vectoring the thrust produced by rotor assemblies **200**A, **200**B using thrust vectoring assembly **250**.

In some embodiments, thrust vectoring assembly **250** of aircraft **100** generally includes an annular first or our gimbal **252**, an annular second or inner gimbal **270**, a pitch control rod **290**, a roll control rod **300**, a pitch actuator or servo **310**, and a roll actuator or servo **320**. The pair of pivot connectors **110** of airframe **102** may extend through outer gimbal **252** at circumferentially opposed (e.g., spaced 180 degrees apart about central axis **105**) locations along the perimeter of outer gimbal **252** to pivotably couple the outer gimbal **252** to the body **104** of airframe **102**. Particularly, a roll control axis **254** may extend through and be defined by the position of pivot connectors **110** whereby outer gimbal **252** and inner gimbal **270** may each pivot relative the airframe **102** about the roll control axis **254**.

The inner gimbal **270** of thrust vectoring assembly **250** may couple with the mount **162** of motor assembly **152** via one or more fasteners (not shown in FIGS. **10**, **11**). Additionally, inner gimbal **270** may be pivotably connected to the outer gimbal **252** by a pair of circumferentially spaced pivot connectors **272** extending radially through the inner gimbal **270** and into a radially inner surface **256** of the outer gimbal **252**. In this configuration, pivot connectors **272** may comprise inner pivot connectors **272** while pivot connectors **110** comprise outer pivot connectors **110**. Each inner pivot connector **272** may be spaced approximately ninety degrees from one of the outer pivot connectors **110**, thereby defining a pitch control axis **274** which extends through inner pivot connectors **272**. In some embodiments, pitch control axis **274** extends orthogonal roll control axis **254**. In addition, roll control axis **254** may extend orthogonally to pitch control axis **274**. Depending on the orientation of outer gimbal **252**, axes **254**, **274** may each be disposed orthogonal the central axis **107** of the body **104** of airframe **102**.

The pitch control rod **290** of thrust vectoring assembly **250** may extend from a first ball joint **292** positioned at a longitudinal first end of pitch control rod **290** to a second ball joint **294** positioned at a longitudinal second end of pitch control rod **290**. The first ball joint **292** of pitch control rod **290** is coupled to an actuator arm **312** that is pivotally coupled to pitch servo **310** at a pivot joint **314**. The second ball joint **294** of pitch control rod **290** is pivotably coupled to the inner surface **256** of outer gimbal **252**. Pitch servo **310** is configured to selectably pivot control arm **312** about a pivot axis defined by pivot joint **314** to linearly displace pitch control rod **290** and, via the pivotable connection between ball joint **294** and outer gimbal **252**, rotate outer gimbal **252** and inner gimbal **270** relative airframe **102** in either rotational direction about pitch control axis **254**.

The roll control rod **300** of thrust vectoring assembly **250** may similarly extend from a first ball joint **302** positioned at a longitudinal first end of roll control rod **300** to a second ball joint **304** positioned at a longitudinal second end of roll control rod **300**. The first ball joint **302** of roll control rod **300** is coupled to a control arm **322** that is pivotally coupled to roll servo **320** at a pivot joint **324**. The second ball joint **304** of roll control rod **300** is pivotably coupled to an outer surface **276** of inner gimbal **270**. Roll servo **320** is configured to selectably pivot control arm **322** about a pivot axis defined by pivot joint **324** to linearly displace roll control rod **300** and, via the pivotable connection between second ball joint **304** and inner gimbal **270**, rotate inner gimbal **270** relative to outer gimbal **252** and airframe **102** in either rotational direction about roll control axis **274**.

Each servo **310**, **320** of thrust vectoring assembly **250** comprises a mount **316**, **326**, respectively, for anchoring each servo **310**, **320** to an inner surface of the body **104** of airframe **102**, thereby restricting relative movement between servos **310**, **320** and airframe **102**. Additionally, each servo **310**, **320** of thrust vectoring assembly **250** may be powered by and electrically connected to the power supply **140** of aircraft **100**. As will be described further herein, each servo **310**, **320** may be independently controlled by the control system **350** of aircraft to selectably control the attitude and trajectory of aircraft **100** once aircraft enters the hover stage at the deployment location (e.g., deployment location **26** shown in FIG. **1**). In some embodiments, aircraft **100** may be controlled by mechanisms other than thrust vectoring assembly **250**, such as via a swash-plate for cyclic and/or collective blade-pitch control for one or both rotor assemblies **200**A, **200**B.

Referring to FIGS. **2**, **3**, **10**, and **11**, Control system **350** of aircraft **100** is generally configured to control the operation of the motor assembly **152** and servos **310**, **320** of aircraft **100** to control the movement of aircraft **100** once aircraft enters the descent and/or hover stages of the flight-path of aircraft **100**. As shown particularly in FIG. **5**, control system **350** may generally include a controller or control board **352**, a first motor controller **360**, and a second motor controller **364**.

Controllers **352**, **360**, and **364** may comprise a singular controller or control board or may comprise a plurality of controllers or control boards that are coupled to one another. Controllers **352**, **360**, and **364** may comprise one or more flexible printed circuit boards (PCB) and/or one or more rigid PCBs with flexible or rigid connections therebetween. Controllers **352**, **360**, and **364** may each comprise at least one processor and associated memory. The one or more processors (e.g., microprocessor, central processing unit (CPU), or collection of such processor devices, etc.) of each controller **352**, **360**, and **364** may execute machine-readable instructions provided on the memory (e.g., non-transitory machine-readable medium) to provide each controller **352**, **360**, and **364** with all the functionality described herein. Additionally, the memory of each controller **352**, **360**, and **364** may comprise volatile storage (e.g., random access memory (RAM)), non-volatile storage (e.g., flash storage, read-only memory (ROM), etc.), or combinations of both volatile and non-volatile storage. Data consumed or produced by the machine-readable instructions of each controller **352**, **360**, and **364** can also be stored on the memory thereof. As noted above, in some embodiments, each controller **352**, **360**, and **364** may comprise a collection of controllers and/or control boards that are coupled to one another. As a result, in some embodiments, each controller **352**, **360**, and **364** may comprise a plurality of the processors, memories, etc.

Controllers **352**, **360**, and **364** may each be powered by and electrically connected to the power supply **140** of aircraft **100**. Controllers **352**, **360**, and **364** may collectively control the motion of aircraft **100** once aircraft **100** has entered the hovering stage at the deployment location. Particularly, aircraft **100** may include a center of mass (COM) **190**, a roll axis **192** extending from the COM **190** of aircraft **100**, a pitch axis **194** extending from COM **190** orthogonally to the roll axis **192**, and a yaw axis **196** extending from COM **190** orthogonally to both the roll axis **192** and pitch axis **194**. Controller **352** may be electrically

connected or otherwise in signal communication with each servo **310**, **320** of thrust vectoring assembly **250** and may control the pitch and roll of aircraft **100** by selectably operating servos **310**, **320**.

For example, during the hovering stage of the trajectory of aircraft **100**, controller **352** may selectably actuate pitch servo **310** to rotate motor assembly **152** (coupled to inner gimbal **270** of thrust vectoring assembly **250**) about pitch control axis **274** to vector the thrust produced by rotor assemblies **200**A, **200**B and thereby induce a pitch moment **193** about the pitch axis **192** of aircraft **100**. Similarly, during the hovering stage of the trajectory of aircraft **100**, controller **352** may selectably actuate roll servo **320** to rotate motor assembly **152** roll control axis **254** to vector the thrust produced by rotor assemblies **200**A, **200**B and thereby induce a roll moment **195** about the roll axis **194** of aircraft **100**. Further, controller **352**, acting through motor controllers **360**, **364**, may independently vary the rotational rate or revolutions per minute (RPM) of each motor **154**, **156** of motor assembly **152** such that the RPM of first motor **154** differs from the RPM of second motor **156**. Given that rotor assemblies **200**A, **200**B counter-rotate, a yaw moment **197** may be induced about the yaw axis **196** of aircraft **100** in response to the creation of a differential RPM between motors **154**, **156**.

Referring to FIGS. **2**, **3**, and **10-12**, a flowchart illustrating a closed-loop feedback control mechanism **370** implemented by control system **350** is shown in FIG. **12**. In some embodiments, control system **350** may include an autopilot, an electronic wireless transmitter and corresponding receiver for receiving inputs **372** from a pilot of aircraft **100**, a ground station **374** positioned distal aircraft **100** (e.g., at the launch location **24** shown in FIG. **1**), and a telemetry module. Aircraft **100** may be equipped with a custom autopilot along with a telemetry module for stability and to transmit data during flight to ground station **374**. The autopilot of control system **350** may utilize a tri-axial accelerometer and a gyroscope to determine the attitude of aircraft **100**, and further, closed-loop feedback control mechanism **370** and pilot inputs **372** (received via the receiver of aircraft **100**) to stabilize and control the hovering fight of aircraft **100** at the deployment location (e.g., deployment location **26** shown in FIG. **1**). Particularly, the attitude of aircraft **100** may be obtained from the measured body-axis angular rates (gyroscope) and the tilt of the gravity vector (accelerometer). These measurements may be filtered and fused to determine the pitch and roll attitude of aircraft **100** during hovering flight. In some embodiments, measurements of the states of aircraft **100** and control inputs (e.g., pilot inputs **372**, etc.) are transmitted from aircraft **100** to the ground station **374**.

As shown particularly in FIG. **12**, an onboard inner loop feedback **376** of feedback control mechanism **370** corresponding to the body states (e.g., body states p, q, r, φ, and θ) of aircraft **100** is provided by controller **352** of control system **350** while an outer loop feedback **378** corresponding to the inertial states (e.g., inertial states x, y, z) of aircraft **100** is provided by the pilot of aircraft **100** via a controls interface as pilot inputs **372**. In some embodiments, the outer loop feedback **378** provided by the pilot may include heave, roll, pitch, and yaw of aircraft **100**.

In some embodiments, electronic control mixing provided by controller **352** provides a plurality of control signals (e.g., pulse width modulated (PWM) signals) for controlling components of aircraft **100**. Particularly, a first control signal **380** may be provided to the first motor controller **360** for controlling the RPM of first motor **154**, and a second control signal **382** may be provided to the second motor controller **364** for controlling the RPM of second motor **156**. In addition, a third control signal **384** may be provided to the pitch servo **310** of thrust vectoring assembly **250** for controlling a command position of pitch servo **310**, and a fourth control signal **386** may be provided to the roll servo **320** of thrust vectoring assembly **250** for controlling a command position of roll servo **320**.

In some embodiments, control signals **380-386** are processed by a proportional-derivative (PD) controller **388** of feedback control mechanism **370**. Particularly, attitude measurements of aircraft **100** (obtained via the accelerometer and gyroscope of aircraft **100**) may be fed to PD controller **388** to stabilize the pitch and roll of aircraft **100**. Yaw of aircraft **100** may be stabilized using a derivative feedback controller. Following processing by PD controller **388**, inner loop feedback **376** is provided to a junction **390** which receives pilot inputs **372** and gains and trims **375** from ground station **374**. Particularly, the pilot or other operator of aircraft **100** may update feedback gains, change trim points, and record telemetry data from the autopilot of controller **352** via ground station **374**.

In other embodiments, the features of feedback control mechanism **370** of control system **350** may vary. For example, in some embodiments, aircraft **100** may fly autonomously during the hovering stage without input from a pilot, eliminating the outer loop feedback **378** provided by pilot controls **372** and/or ground station **374**. Additionally, in some embodiments, a controller other than PD controller **388** may be used, such as a proportional-integral-derivative (PID) controller or other model-based controllers.

In some embodiments, aircraft **100** may include additional sensors and other equipment for performing one or more functions (e.g., ISR, etc.) as aircraft **100** loiters at the deployment location. In some embodiments, sensor data may be transmitted to the pilot or other operator of aircraft **100** via ground station **374**, thereby permitting the operator of aircraft **100** to obtain data pertaining to the deployment location.

The configuration of rotary-wing aircraft which may be utilized in projectile-launched aircraft systems (e.g., system **10**) may vary from the configuration of aircraft **100** shown in FIGS. **2-12**. For example, referring to FIG. **13**, another embodiment of an unmanned hover-capable, rotary-wing aircraft **400** is shown. Aircraft **400** may include features in common with aircraft **100**, such as the configuration of control system **350**. However, unlike aircraft **100** which includes a thrust vectoring assembly **250** having nested outer and inner gimbals **252**, **270**, respectively, aircraft **400** may include two separate and distinct gimbals and rotor assemblies positioned at opposite longitudinal ends of aircraft **400**.

Particularly, aircraft **400** has a first longitudinal end **401**, a second longitudinal end **403** opposite the first longitudinal end **401**, a central or longitudinal axis **405**, and may generally include an airframe **402**, a first thrust vectoring assembly **420**, a second thrust vectoring assembly **440**, a first rotor assembly **460**, and a second rotor assembly **480**. First thrust vectoring assembly **420** may include a single gimbal **422** pivotable about a first pivot axis **424** extending orthogonal the central axis **405** of aircraft **400**. A first motor **430** of aircraft **400** may be positioned within the first gimbal **424** for rotating the first rotor assembly **460**, the first motor **430** and first rotor assembly **460** each being rotatable about the first pivot axis **424** relative to the airframe **402**. First rotor assembly **460** is positioned at the first longitudinal end **401** of aircraft **400** and includes a pair of rotor blades **462** and a rotor hub **464** located centrally with respect to rotor blades **462**. A radially inner end or root of each rotor blade **462** may be pivotably connected to rotor hub **464** via a pivot joint **466**.

The second thrust vectoring assembly **440** of aircraft **400** may include a single gimbal **442** pivotable about a second pivot axis **444** extending orthogonal the central axis **405** of aircraft **400**. Additionally, second pivot axis **444** may extend orthogonal to the first pivot axis **424** of first thrust vectoring assembly **420**. A second motor **450** of aircraft **400** may be positioned within the second gimbal **444** for rotating the second rotor assembly **480**, the second motor **450** and second rotor assembly **480** each being rotatable about the second pivot axis **444** relative to the airframe **402**. Second rotor assembly **480** is positioned at the second longitudinal end **403** of aircraft **400** and includes a pair of rotor blades **482** and a rotor hub **484** located centrally with respect to rotor blades **482**. A radially inner end or root of each rotor blade **482** may be pivotably connected to rotor hub **484** via a pivot joint **486**.

Second rotor assembly **480** may counter-rotate relative first rotor assembly **460** but may, when oriented as shown in FIG. **13**, produce a singular thrust vector. Additionally, airframe **402** of aircraft **400** may include a first pair of recesses **404** for receiving the rotor blades **462** of first rotor assembly **460**, and a second pair of recesses **406** for receiving the rotor blades **482** of second rotor assembly **480** when each rotor assembly is in a stowed configuration.

Referring to FIG. **14**, another embodiment of an unmanned hover-capable, rotary-wing aircraft **500** is shown. Aircraft **500** may include features in common with aircraft **100**, and shared features are labeled similarly. Particularly, aircraft **500** is similar in configuration except that, instead of nose **130**, the airframe **502** of aircraft **500** comprises a tail **504** that includes a longitudinal first end **506**, a longitudinal second end **508** opposite the first end **506**, and a fin or stabilizer **509** proximal second end **508** for stabilizing the flight of aircraft **500** following the launch of aircraft **500** from a projectile launcher (e.g., projectile launcher **12** shown in FIG. **1**). In some embodiments, aircraft **500** may be configured to be launched along a vertical flightpath (indicated by arrow **510** in FIG. **14**) from the projectile launcher. Particularly, within a launch tube of the projectile launcher, the tail **504** of aircraft **500** may be positioned adjacent a cartridge (e.g., cartridge **16** of FIG. **1**) of the projectile launcher. Thus, unlike the loading of aircraft **100** described above, rotor assemblies **200**A, **200**B of aircraft **500** may be positioned opposite the cartridge of the projectile launcher when aircraft **500** is loaded into the projectile launcher prior to being launched along the vertical flightpath **510**.

While embodiments of the disclosure have been shown and described, modifications thereof can be made by one skilled in the art without departing from the scope or teachings herein. The embodiments described herein are exemplary only and are not limiting. Many variations and modifications of the systems, apparatus, and processes described herein are possible and are within the scope of the disclosure. For example, the relative dimensions of various parts, the materials from which the various parts are made, and other parameters can be varied. Accordingly, the scope of protection is not limited to the embodiments described herein, but is only limited by the claims that follow, the scope of which shall include all equivalents of the subject matter of the claims. Unless expressly stated otherwise, the steps in a method claim may be performed in any order. The recitation of identifiers such as (a), (b), (c) or (1), (2), (3) before steps in a method claim are not intended to and do not specify a particular order to the steps, but rather are used to simplify subsequent reference to such steps.

What is claimed is:

1. A projectile-launched aircraft system, comprising:

a projectile launcher comprising a triggering mechanism;

a rotary-wing, hover-capable aircraft having a first end and a second end longitudinally opposite the first end, wherein the aircraft comprises:

an airframe;

a rotor assembly located at the first end and that comprises at least one rotor blade, wherein the rotor blade comprises a stowed configuration and a deployed configuration that is circumferentially spaced from the stowed configuration about a pivot axis;

a motor assembly coupled to the rotor assembly and configured to rotate the at least one rotor blade; and

a thrust vectoring assembly comprising an annular gimbal assembly having a receptacle that receives the motor assembly whereby the motor assembly is permitted to pivot relative to the airframe about a pair of orthogonal axes;

a cover having one or more exterior fins and, wherein the cover is coupled to the aircraft at the first end thereof when the aircraft is in the stowed configuration and separated from the aircraft when the aircraft is in the deployed configuration;

wherein, upon actuation of the triggering mechanism, the projectile launcher is configured to launch the aircraft, with the second end of the aircraft located upstream from the first end, along a flightpath.

2. The system of claim 1, wherein the projectile launcher comprises a barrel configured to receive the aircraft and a cartridge comprising a propellant, and wherein the triggering mechanism is configured to initiate the propellant to launch the aircraft from the barrel.

3. The system of claim 1, wherein the flightpath comprises at least one of a vertical flightpath and a ballistic flightpath.

4. The system of claim 1, wherein the aircraft comprises a control system configured to operate the motor to hover the aircraft at a deployment location that is spaced from the projectile launcher.

5. The system of claim 1, wherein the aircraft comprises:

an outer surface defined by the airframe and comprising at least one first recess formed therein;

wherein the first rotor blade is at least partially received in the first recess of the airframe when in the stowed configuration.

6. The system of claim 5, wherein the aircraft comprises:

at least one second rotor blade that is spaced along a longitudinal axis of the aircraft from the first rotor blade;

wherein the outer surface of the airframe comprises at least one second recess formed therein; and

wherein the second rotor blade comprises a stowed configuration and a deployed configuration that is circumferentially spaced from the stowed configuration about a second pivot axis, and wherein the second rotor blade is at least partially received in the second recess of the airframe when in the stowed configuration.

7. The system of claim 6, wherein the gimbal assembly comprises a first gimbal pivotably coupled to the airframe whereby the first gimbal is permitted to pivot relative to the airframe about a first axis of the pair of orthogonal axes, wherein the first rotor blade is coupled to the first gimbal and is permitted to pivot about the first axis relative to the airframe.

8. The system of claim 7, wherein: the annular gimbal assembly comprises a second gimbal pivotably coupled to the airframe whereby the second gimbal is permitted to pivot relative to the airframe about a second axis of the pair of orthogonal axes;

at least one of the first rotor assembly and the second rotor blade is coupled to the second gimbal and is permitted to pivot about the second axis relative to the airframe.

9. The system of claim 8, wherein the aircraft comprises:

a first servo configured to adjust a position of the first gimbal about the first axis;

a second servo configured to adjust a position of the second gimbal about the second axis; and

a control system configured to operate the first servo to control a pitch of the aircraft, operate the second servo to control a roll of the aircraft, and to operate the motor assembly to control a yaw of the aircraft.

10. A rotary-wing, hover-capable aircraft, comprising:

an airframe comprising an outer surface that comprises at least one first recess formed therein;

a first rotor assembly rotatably coupled to the airframe and comprising at least one first rotor blade;

a motor assembly coupled to the first rotor assembly and configured to rotate the at least one first rotor blade; an

a thrust vectoring assembly comprising an annular gimbal assembly having a receptacle that receives the motor assembly whereby the motor assembly is permitted to pivot relative to the airframe about a pair of orthogonal axes;

wherein the first rotor blade comprises a stowed configuration and a deployed configuration that is circumferentially spaced from the stowed configuration about a first pivot axis, and wherein the first rotor blade is at least partially received in the first recess of the airframe when in the stowed configuration.

11. The aircraft of claim 10, further comprising:

a second rotor assembly rotatably coupled to the airframe and comprising at least one second rotor blade, wherein the second rotor assembly is spaced along a longitudinal axis of the aircraft from the first rotor assembly;

wherein the outer surface of the airframe comprises at least one second recess formed therein; and

wherein the second rotor blade comprises a stowed configuration and a deployed configuration that is circumferentially spaced from the stowed configuration about a second pivot axis, and wherein the second rotor blade is at least partially received in the second recess of the airframe when in the stowed configuration.

12. The aircraft of claim 11, wherein the motor assembly comprises a first motor configured to rotate the first rotor blade in a first rotational direction, and a second motor configured to rotate the second rotor blade in a second rotational direction opposite the first rotational direction.

13. The aircraft of claim 11, wherein the annular gimbal assembly comprises a first gimbal pivotably coupled to the airframe whereby the first gimbal is permitted to pivot relative to the airframe about a first axis, wherein the first rotor assembly is coupled to the first gimbal and is permitted to pivot about the first axis relative to the airframe.

14. The aircraft of claim 13, wherein:

the annular gimbal assembly comprises a second gimbal pivotably coupled to the airframe whereby the second gimbal is permitted to pivot relative to the airframe about a second axis that extends orthogonally to the first axis; and at least one of the first rotor assembly and the second rotor assembly is coupled to the second gimbal and is permitted to pivot about the second axis relative to the airframe.

15. The aircraft of claim **14**, wherein the second gimbal is positioned radially within the first gimbal and is configured to pivot about both the first axis and the second axis relative to the airframe, and wherein the first rotor assembly is coupled to the second gimbal.

16. The aircraft of claim **14**, further comprising:

a first servo configured to adjust a position of the first gimbal about the first axis;

a second servo configured to adjust a position of the second gimbal about the second axis; and

a control system configured to operate the first servo to control a pitch of the aircraft, operate the second servo to control a roll of the aircraft, and to operate the motor assembly to control a yaw of the aircraft.

17. The aircraft of claim **10**, wherein the aircraft comprises a first rotor assembly that comprises a plurality of circumferentially spaced first rotor blades and a rotor hub centrally positioned between the plurality of first rotor blades, and wherein a radially inner end of each first rotor blade couples to the rotor hub at one of a plurality of hinges.

18. A method for directing a rotary-wing, hover-capable aircraft along a flightpath, comprising:

(a) launching the aircraft from a projectile launcher positioned at a launch location such that a rotor assembly of the aircraft is located at a downstream end thereof as the aircraft is launched from the projectile launcher;

(b) actuating a rotor blade of the rotor assembly of the aircraft from a stowed configuration to a deployed configuration that is circumferentially spaced from the stowed configuration about a pivot axis;

(c) activating a motor assembly coupled to the rotor assembly to rotate the rotor blade;

(d) activating a thrust vectoring assembly comprising an annular gimbal assembly having a receptacle that receives the motor assembly to pivot the motor assembly relative to an airframe of the aircraft about a pair of orthogonal axes; and

(e) hovering the aircraft at a deployment location that is spaced from the launch location.

19. The method of claim **18**, wherein the first rotor blade is received in a recess formed in an outer surface of the airframe of the aircraft when the first rotor blade is in the stowed configuration.

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